PROCEEDINGS

OF THE

FOURTEENTH ANNUAL CONVENTION

OF THE

American Railway Engineering Association

HELD AT THE

CONGRESS HOTEL, CHICAGO, ILLINOIS

March 18, 19 and 20, 1913

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PART I

CONSTITUTION

CONSTITUTION.

REVISED AT THE FIFTH, EIGHTH AND TWELFTH ANNUAL CONVENTIONS.

ARTICLE I.

NAME, OBJECT AND LOCATION.

Name.

1. The name of this Association is the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Object.

2. Its object is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

Means to be Used.

3. The means to be used for this purpose shall be as follows:

(a) Meetings for the reading and discussion of reports and papers and for social intercourse.

(b) The investigation of matters pertaining to the objects of this Association through Standing and Special Committees.

(c) The publication of papers, reports and discussions.

(d) The maintenance of a library.

Responsibility.

4. Its action shall be recommendatory, and not binding upon its members.

Location of Office.

5. Its permanent office shall be located in Chicago, Ill., and the annual convention shall be held in that city.

ARTICLE II.

MEMBERSHIP.

Membership Classes.

1. The membership of this Association shall be divided into three classes, viz.: Members, Honorary Members and Associates.

Membership Qualifications.

(2) A Member shall be:

(a) Either a Civil Engineer, a Mechanical Engineer, an Electrical Engineer, or an official of a railway corporation, who has had not less than five (5) years' experience in the location, construction, maintenance or operation of railways, and who, at the time of application for membership, is engaged in railway service in a responsible position in charge of work connected with the Location, Construction, Operation or Maintenance of a Railway; provided, that all persons who were Active Members prior to March 20, 1907, shall remain Members except as modified by Article II, Clause 9.

(b) A Professor of Engineering in a college of recognized standing.

Honorary Membership Qualifications.

3. An Honorary Member shall be a person of acknowledged eminence in railway engineering or management. The number of Honorary Members shall be limited to ten.

Associate Membership Qualifications.

4. An Associate shall be a person not eligible as a Member, but whose pursuits, scientific acquirements or practical experience qualify him to co-operate with Members in the advancement of professional knowledge, such as Consulting, Inspecting, Contracting, Government or other Engineers, Instructors of Engineering in Colleges of recognized standing, and Engineers of Industrial Corporations when their duties are purely technical.

Membership Rights.

5. (a) Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights of Members, except that of holding office, and shall be exempt from the payment of dues.

(c) Associates shall have all the rights of Members, except those of voting and holding office.

Age Requirement.

6. An applicant to be eligible for membership in any class shall not be less than twenty-five (25) years of age.

"Railway" Defined.

7. The word "railway" in this Constitution means one operated by steam or electricity as a common carrier, dependent upon transportation for its revenue. Engineers of street railway systems and of railways which are used primarily to transport the material or product of an industry or industries to and from a point on a railway which is a common carrier, or those which are merely adjuncts to such industries, are eligible only as Associates.

Changes in Classes.

8. A Member, elected after March 20, 1907, who shall leave the railway service, shall cease to be a Member, but may retain membership in the Association as an Associate, subject to the provisions of Article II, Clause 9; provided, however, if he re-enters the railway service, he shall be restored to the class of Members.

Supply Men.

9. Persons whose principal duties require them to be engaged in the sale or promotion of railway patents, appliances or supplies, shall not be eligible for, nor retain membership in any class in this Association, except that those who were Active Members prior to March 20, 1907, may retain membership as Associates; provided, however, that anyone having held membership in the Association and subsequently having become subject to the operation of this clause, shall, if he again becomes eligible, be permitted to re-enter the Association, without the payment of a second entrance fee.

Transfers.

10. The Board of Direction shall transfer members from one class to another, or remove a member from the membership list, under the provisions of this Article.

ARTICLE III.

ADMISSIONS AND EXPULSIONS.

Charter Membership.

1. The Charter Membership consists of all persons who were elected before March 15, 1900.

Application for Membership.

2. The Charter Membership having been completed, any person desirous of becoming a member shall make application upon the form prescribed by the Board of Direction, setting forth in a concise statement his name, age, residence, technical education and practical experience. He shall refer to at least three members to whom he is personally known, each of whom shall be requested by the Secretary to certify to a personal knowledge of the candidate and his fitness for membership.

Election to Membership.

3. Upon receipt of an application properly endorsed, the Board of Direction, through its Secretary, or a Membership Committee selected from its own members, shall make such investigation of the candidate's fitness as may be deemed necessary. The Secretary will furnish copies of the information obtained and of the application to each member of the Board of Direction. At any time, not less than thirty days after the filing of the application, the admission of the applicant shall be canvassed by letter-ballot among the members of the Board, and affirmative votes by two-thirds of its members shall elect the candidate; provided, however, that should an applicant for membership be personally unknown to three members of the Association, due to residence in a foreign country, or in such a portion of the United States as precludes him from a sufficient acquaintance with its members, he may refer to well-known men engaged in railway or allied professional work, upon the form above described, and such application shall be considered by the Board of Direction in the manner above set forth, and the applicant may be elected to membership by a unanimous vote of the Board.

Subscription to Constitution.

4. All persons, after due notice from the Secretary of their election, shall subscribe to the Constitution on the form prescribed by the Board of Direction. If this provision be not complied with within six months of said notice, the election shall be considered null and void.

Reinstatement.

5. Any person having been a member of this Association, and having, while in good standing, resigned such membership, may be reinstated without the payment of a second entrance fee; provided his application for reinstatement is signed by five members certifying to his fitness for same, and such application is passed by a two-thirds majority of the Board of Direction.

Honorary Membership.

6. Proposals for Honorary Membership shall be submitted by ten or more Members. Each Member of the Board of Direction shall be furnished with a copy of the proposal, and if, after thirty days, the nominee shall receive the unanimous vote of said Board, he shall be declared an Honorary Member.

Expulsions.

7. When charges are preferred against a Member in writing by ten or more Members, the Member complained of shall be served with a copy of such charges, and he shall be called upon to show cause to the Board of Direction why he should not be expelled from the Association. Not less than thirty days thereafter a vote shall be taken on his expulsion, and he shall be expelled upon a two-thirds vote of the Board of Direction.

Resignations.

8. The Board of Direction shall accept the resignation, tendered in writing, of any Member whose dues are fully paid up.

ARTICLE IV.

DUES.

Entrance Fee.

1. An entrance fee of $10.00 shall be payable to the Association through its Secretary with each application for membership; and this sum shall be returned to the applicant if not elected.

Annual Dues.

2. The annual dues are $10.00, payable during the first three months of the calendar year.

Arrears.

3. Any person whose dues are not paid before April 1st of the current year shall be notified of same by the Secretary. Should the dues not be paid prior to July 1st, the delinquent Member shall lose his right to vote. Should the dues remain unpaid October 1st, he shall be notified on the form prescribed by the Board of Direction, and he shall no longer receive the publications of the Association. If the dues are not paid by December 31st, he shall forfeit his membership without further action or notice, except as provided for in Clause 4 of this Article.

Remission of Dues.

4. The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, who, from ill-health, advanced age or other good reasons, is unable to pay them.

ARTICLE V.

OFFICERS.

Officers.

1. The officers of the Association shall be Members and shall consist of:

A President,
A First Vice-President,
A Second Vice-President,
A Treasurer,
A Secretary,
Nine Directors,

who, together with the five latest living Past-Presidents who are Members, shall constitute the Board of Direction in which the government of the Association shall be vested, and who shall act as Trustees, and have the custody of all property belonging to the Association.

Vice-Presidents' Priority.

2. The offices of First and Second Vice-Presidents shall be determined by the priority of their respective dates of election.

Terms of Office.

3. The terms of office of the several officers shall be as follows:

President, one year.
Vice-Presidents, two years.
Treasurer, one year.
Secretary, one year.
Directors, three years.

Officers Elected Annually.

4. (a) There shall be elected at each Annual Convention:

A President,
One Vice-President,
A Treasurer,
A Secretary,
Three Directors.

(b) The candidates for President and for Vice-President shall be selected from the members of the Board of Direction.

5. The office of President shall not be held twice by the same person. A person who shall have held the office of Vice-President or Director shall not be eligible for re-election to the same office until at least one full term shall have elapsed after the expiration of his previous term of office. Conditions of Re-election of Officers.

6. The term of each officer shall begin with his election and continue until his successor is elected. Term of Officers.

7. (a) A vacancy in the office of President shall be filled by the First Vice-President. Vacancies in Offices.

(b) A vacancy in the office of either of the Vice-Presidents shall be filled by the Board of Direction by election from the Directors. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) Any other vacancies for the unexpired term in the membership of the Board of Direction shall be filled by the Board.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office he is holding; provided, however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provision of Article V, Clause 5.

8. When an officer ceases to be a Member of the Association, as provided in Article II, his office shall be vacated, and be filled as provided in Article V, Clause 7. Vacation of Office.

9. In case of the disability or neglect in the performance of his duty, of an officer, the Board of Direction, by a two-thirds majority vote of the entire Board, shall have power to declare the office vacant, and fill it as provided in Article V, Clause 7. Disability or Neglect.

ARTICLE VI.

NOMINATION AND ELECTION OF OFFICERS.

1. (a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members not officers. Nominating Committee.

(b) The five Members shall be elected annually when the officers of the Association are elected.

2. It shall be the duty of this committee to nominate candidates to fill the offices named in Article V, and vacancies in the Nominating Committee caused by expiration of term of service, for the ensuing year, as follows: Number of Candidates.

Office to be Filled.	Number of Candidates to be named by Nominating Committee.	Number of Candidates to be elected at Annual Election of Officers.
President	1	1
Vice-President	1	1
Treasurer	1	1
Secretary	1	1
Directors	9	3
Nominating Committee	10	5

Chairman.

3. The Senior Past-President shall act as permanent chairman of the committee, and will issue the call for meetings. In his absence from meetings, the Past-President next in age of service shall act as Chairman pro tem. at the meeting.

Meeting of Committee.

4. Prior to December 1st, each year, the Chairman shall call a meeting of the committee at a convenient place and, at this meeting, nominees for office shall be agreed upon.

Announcement of Names of Nominees.

5. The names of the nominees shall be announced by the permanent Chairman to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the Members of the Association on a printed slip not later than January 1st following.

Additional Nominations by Members.

6. At any time between January 1st and February 1st, any ten or more Members may send to the Secretary additional nominations for the ensuing year signed by such Members.

Vacancies in List of Nominees.

7. If any person so nominated shall be found by the Board of Direction to be ineligible for the office for which he is nominated, or should a nominee decline such nomination, his name shall be removed and the Board may substitute another one therefor; and may also fill any vacancies that may occur in this list of nominees up to the time the ballots are sent out.

Ballots Issued.

8. Not less than thirty days prior to each Annual Convention, the Secretary shall issue ballots to each voting member of record in good standing, with a list of the several candidates to be voted upon, with the names arranged in alphabetical order when there is more than one name for any office.

Substitution of Names.

9. Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

Ballots.

10. (a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and may substitute another, at any time before the polls close.

Invalid Ballots.

11. Ballots not endorsed or from persons not qualified to vote shall not be opened; and any others not complying with the above provisions shall not be counted.

Closure of Polls.

12. The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by three tellers appointed by the Presiding Officer. The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

Requirements for Election.

13. The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

Tie Vote.

14. In case of a tie between two or more candidates for the same office, the members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

15. The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article. Announcement.

16. Except as to the Past-Presidents, the first Nominating Committee and the three additional Directors provided for shall be appointed by the Board of Direction, one of the Directors for one year, one for two years, and one for three years. First Nominating Committee.

ARTICLE VII.

MANAGEMENT.

1. (a) The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio member of all Committees, except the Nominating Committee. Duties of President.

(b) The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and discharge his duties in case of a vacancy in his office.

2. The Treasurer shall receive all moneys and deposit same in the name of the Association, and shall receipt to the Secretary therefor. He shall invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. He shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction. Duties of Treasurer.

3. The Secretary shall be, under the direction of the President and Board of Direction, the Executive Officer of the Association. He shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. He shall see that the moneys due the Association are collected and without loss transferred to the custody of the Treasurer. He shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. He is to conduct the correspondence of the Association and keep proper record thereof, and perform such other duties as the Board of Direction may prescribe. Duties of Secretary.

4. The accounts of the Treasurer and Secretary shall be audited annually by a public accountant, under the direction of the Finance Committee of the Board. Auditing of Accounts.

5. The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution. Duties of Board.

6. The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board. Board Meetings.

7. Seven members of the Board shall constitute a quorum. Board Quorum.

8. At the first meeting of the Board after the Annual Convention, the following committees from its members shall be appointed by the President, and shall report to and perform their duties under the supervision of the Board of Direction: Board Committees.

a. Finance Committee of three members.
b. Publication Committee of three members.
c. Library Committee of three members.
d. Outline of Work of Standing Committees of five members.

Duties of Finance Committee.

9. The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of moneys and as to other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by previous action and authority of the Board of Direction.

Duties of Publication Committee.

10. The Publication Committee shall have general supervision of the publications of the Association.

Duties of Library Committee.

11. The Library Committee shall have general supervision of the Library, the property therein, and the quarters occupied by the Secretary; shall make recommendations to the Board with reference thereto; and shall direct the expenditure for books and other articles of permanent value, from such sums as may be appropriated for these purposes.

Duties of Committee or Outline of Work of Standing Committees.

12. The Committee on Outline of Work of Standing Committees shall present a list of subjects for committee work during the ensuing year at the first meeting of the Board of Direction after the Annual Convention.

Standing Committees.

13. The Board of Direction may appoint such Standing Committees as it may deem best, to investigate, consider and report upon questions pertaining to railway location, construction or maintenance.

Special Committees.

14. Special Committees to examine into and report upon any subject connected with the objects of this Association may be appointed from time to time by the Board of Direction.

Discussion by Non-Members.

15. The Board of Direction may invite discussions of reports from persons not members of the Association.

Sanction of Acts of Board.

16. An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next Annual Convention of the Association shall be deemed to be the act of the Association, and shall not afterwards be impeached by any Member.

ARTICLE VIII.

MEETINGS.

Annual Convention.

1. The Annual Convention shall begin upon the third Tuesday in March of each year, and shall be held at such place in the City of Chicago as the Board of Direction may select.

Special Meetings.

2. Special meetings of the Association may be called by the Board of Direction, and special meetings shall be so called by the Board upon request of thirty Members, which request shall state the purpose of such meeting. The call for such meeting shall be issued not less than ten days in advance, and shall state the purpose and place thereof, and no other business shall be taken up at such meeting.

3. The Secretary shall notify all members of the time and place of the Annual Convention of the Association at least thirty days in advance thereof. Notification of Annual Convention.

4. Twenty-five Members shall constitute a quorum at all meetings of the Association. Association Quorum.

5. (a) The order of business at annual conventions of the Association shall be as follows: Order of Business.

Reading of minutes of last meeting.
Address of the President.
Reports of the Secretary and Treasurer.
Reports of Standing Committees.
Reports of Special Committees.
Unfinished business.
New business.
Election of officers.
Adjournment.

(b) This order of business, however, may be changed by a majority vote of members present.

6. The proceedings shall be governed by "Robert's Rules of Order," except as otherwise herein provided. Rules of Order.

7. Discussion shall be limited to members and to those invited by the presiding officer to speak. Discussion.

ARTICLE IX.

AMENDMENTS.

1. Proposed amendments to this Constitution shall be made in writing and signed by not less than ten Members, and shall be acted upon in the following manner: Amendments.

The amendments shall be presented to the Secretary, who shall send a copy of same to each member of the Board of Direction as soon as received. If at the next meeting of the Board of Direction a majority of the entire Board are in favor of considering the proposed amendments, the matter shall then be submitted to the Association for letter-ballot, and the result announced by the Secretary at the next Annual Convention. In case two-thirds of the votes received are affirmative, the amendments shall be declared adopted and become immediately effective.

GENERAL INFORMATION.

(Subject to change from time to time by Board of Direction.)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS.

(A) APPOINTMENT OF COMMITTEES AND OUTLINE OF WORK.

Standing Committees.

1. The following are standing committees:

I. Roadway.
II. Ballast.
III. Ties.
IV. Rail.
V. Track.
VI. Buildings.
VII. Wooden Bridges and Trestles.
VIII. Masonry.
IX. Signs, Fences and Crossings.
X. Signals and Interlocking.
XI. Records and Accounts.
XII. Rules and Organization.
XIII. Water Service.
XIV. Yards and Terminals.
XV. Iron and Steel Structures.
XVI. Economics of Railway Location.
XVII. Wood Preservation.
XVIII. Electricity.
XIX. Conservation of Natural Resources.

Special Committees.

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Clause 14, of the Constitution.

Personnel of Committees.

3. The personnel of all Committees will continue from year to year, except when changes are announced by the Board of Direction.

Members of committees who do not attend meetings of committees during the year or render service by correspondence will be relieved and the vacancies filled by the Board at the succeeding annual convention.

Outline of Work.

4. As soon as practicable after each annual convention the Board of Direction will assign to each Committee the important questions which, in its judgment, should preferably be considered during the current year. Committees are privileged to present the results of any special study or investigation they may be engaged upon or that may be considered of sufficient importance to warrant presentation.

(B) PREPARATION OF COMMITTEE REPORTS.

General.

5. The collection and compilation of data and subsequent analysis in the form of arguments and criticism is a necessary and valuable preliminary element of committee work.

6. Committees are privileged to obtain data or information in any proper way. If desired, the Secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blue-print. Collection of Data.

7. Committee reports should be prepared as far as practicable to conform to the following general plan: Plan of Reports

(a) It is extremely important that every Committee should examine its own subject-matter in the "Manual" prior to each annual convention, and revise and supplement it, if deemed desirable, giving the necessary notice of any recommended changes in accordance with Clause 6 (a) of the General Rules for the Publication of the "Manual." If no changes are recommended, statement should be made accordingly.

(b) When deemed necessary, the previous report should be reviewed.

(c) Subjects presented in previous reports on which no action was taken should be resubmitted, stating concisely the action desired. It may not be necessary to repeat the original text in the report, reference to former publication being sufficient, unless changes in the previously published version are extensive. Minor changes can be explained in the text of the report.

(d) Technical terms used in the report, the meaning of which is not clearly established, should be defined, but defined only from the standpoint of railway engineering. Definitions.

(e) If necessary, a brief history of the subject-matter under discussion, with an outline of its origin and development, should be given. History.

(f) An analysis of the most important elements of the subject-matter should be given. Analysis.

(g) The advantages and disadvantages of the present and recommended practices should be set forth. Argument.

(h) Illustrations accompanying reports should be prepared so that they can be reproduced on one page. The use of folders should be avoided as much as possible, on account of the increased expense and inconvenience in referring to them. Plans showing current practice, or necessary for illustration, are admissible, but those showing proposed definite design or practice should be excluded. Recommendatoins should be confined to governing principles. Illustrations

Illustrations should be made on tracing cloth with heavy black lines and figures, so as to stand a two-thirds reduction; for example: To come within a type page (4 inches by 7 inches), the illustration should be made three times the above size.

To insure uniformity, the one-stroke, inclined Gothic lettering is recommended.

Photographs should be clear and distinct silver prints.

Conclusions.

Plans showing current practice, or necessary for illustration, are admissible, but those showing proposed definite design or practice should be excluded. Recommendations should be confined to governing principles.

(i) The conclusions of the Committee which are recommended for publication in the Manual should be stated in concise language, logical sequence, and grouped together, setting forth the principles, specifications, definitions, forms, tables and formulæ included in the recommendation. Portions of the text of the report which are essential to a clear interpretation and understanding of the conclusions, should be included as an integral part thereof.

(c) PUBLICATION OF COMMITTEE REPORTS.

Reports Required.

8. (a) Reports will be required from each of the Standing and Special Committees each year.

(b) Although several subjects may be assigned to each Committee by the Board of Direction, a full report on only one subject is expected at each annual convention, but the preliminary work on some of the remaining subjects should be in progress, and, when deemed advisable, partial reports of progress should also be presented. This method allows time for their proper preparation and consideration.

Date of Filing Reports.

9. Committee reports to come before the succeeding convention for discussion should be filed with the Secretary not later than November, 30 of each year.

10. Committees engaged upon subjects involving an extended investigation and study are privileged to present progress reports, giving a brief statement of the work accomplished, and, if deemed expedient, a forecast of the final report to be presented.

Publication of Reports.

11. Committee reports will be published in the Bulletin in such sequence as the Board of Direction may determine, for consideration at the succeeding convention. Reports will be published in the form presented by the respective Committees. Alterations ordered by the convention will be printed as an appendix to the report.

Written Discussions.

12. Committees should endeavor to secure written discussions of published reports. Written discussions will be transmitted to the respective Committees, and if deemed desirable by the Committee, the discussions will be published prior to the convention and be considered in connection with the report.

Verbal Discussions.

13. Each speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

(d) CONSIDERATION OF COMMITTEE REPORTS.

Sequence.

14. The sequence in which Committee reports will be considered by the convention will be determined by the Board of Direction.

15. The method of consideration of Committee reports will be one of the following: Method.

(a) Reading by title.

(b) Reading, discussing and acting upon each conclusion separately.

(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

16. Action by the convention on Committee reports will be one of the following, after discussion is closed: Final Action.

(a) Receiving as information.

(b) Receiving as a progress report.

(c) Adoption of a part complete in itself and referring remainder back to Committee.

(d) Adoption as a whole.

(e) Recommittal with or without instructions.

(f) Adoption as a whole.

(g) Recommendation to publish in the Manual.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the Committee considers affected.

The Chair will decline to entertain amendments which in his opinion lie entirely within the duties of the Editor.

(E) PUBLICATION BY TECHNICAL JOURNALS.

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the Bulletin; provided application therefor is made in writing and proper credit be given the Association, authors or Committees presenting such material.

GENERAL RULES FOR THE PUBLICATION OF THE "MANUAL."

Title.

1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall edit the Manual and shall have authortiy to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Adoption of Reports Not Binding.

3. Matters adopted by the Association and subsequently published in the Manual shall be considered in the direction of good practice, but shall not be binding on the members.

Contents.

4. The Manual will only include conclusions relating to definitions, specifications and principles of practice as have been made the subject of a special study by a Standing or Special Committee and embodied in a committee report, published not less than thirty days prior to the annual convention, and submitted by the Committee to the annual convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction, should be reviewed by the American Railway Association, may be referred to that Association before being published in the Manual.

5. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the Committee report and subsequent discussion and the final action of the Association.

Revision.

6. Any matter published in the Manual may be amended or withdrawn by vote at any subsequent annual convention, provided such changes are proposed in time for publication not less than thirty days prior to the annual convention, and in the following manner: (a) Upon recommendation of the Committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members, made to the Board of Direction.

7. The Manual will be revised either by publishing a new edition or a supplemental pamphlet as promptly as possible after each annual convention.

BUSINESS SESSION

PROCEEDINGS.

The object of this Association is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways. Its action is not binding upon its members.

TUESDAY, MARCH 18, 1913.

MORNING SESSION.

The convention was called to order by the President, Mr. Chas. S. Churchill, Chief Engineer of the Norfolk & Western Railway, at 9:15 o'clock.

The President:—Gentlemen, please come to order.

The Fourteenth Annual Convention of the American Railway Engineering Association is now declared in session. This convention will witness the work of the Association under an improved Constitution and organization of committees, and this meeting will be held under very favorable auspices.

The Committee on Arrangements and our Secretary have arranged a program after several months' work that will, we think, prove very interesting.

The Railway Age-Gazette and the Railway and Engineering Review will publish daily issues of the proceedings, which will add greatly to the interest and enthusiasm, and I am sure they will have the thanks of the members.

The privileges of the floor of this convention are, as usual, tendered to railway officials and to Engineers who may not be members of the Association, and to others who are interested in the subjects under discussion, and they are invited to add to the interest of the meetings in any way they may think desirable.

It is requested that when gentlemen rise for recognition by the Chair they will announce their names and the name of the company with which they are connected, and in case they are not members of the Association, they will indicate their business or the college they represent.

The first business before the convention is the reading of the Minutes of the last annual convention. These Minutes have been in print for a long time and a copy furnished to each member, and unless there is objection, they will be accepted and considered approved as printed. There being no objection, the Minutes stand approved as printed.

The next order of business is the customary address of the President.

PRESIDENT'S ADDRESS.

ASSOCIATION AFFAIRS.

To the Members of the American Railway Engineering Association:

On January 1, 1912, our membership aggregated 1,004. During the past year there has been an increase of 62, making a total of 1,066. The number of printed pages issued during the year was as follows:

	Pages.
In Bulletins	1,542
In Proceedings	1,364
In Manual, Program and Miscellaneous	320
Total	3,226

The aggregate to date issued by this Association is therefore. 30,366

The various methods reported upon at the last convention for increasing revenues, especially those procurable by economies, have been carried out, with the result that on January 1, 1913, our cash on hand was $3,183.11 in excess of what it was on January 1, 1912. One of the economies that have contributed to this favorable showing is the present method of binding and printing. The two parts of Vol. No. 12 of 1911 contain about the same number of pages as the single issue of Vol. No. 13 for 1912.

The total saving of Vol. 13 as compared with Vol. 12 was $1,128.28, to which should be added other reductions in cost of mailing.

Another advantage of the present method of printing is the securing of our Proceedings in one volume of convenient size upon a date nearly six months earlier than heretofore. In fact, our Secretary estimates that the Proceedings of this convention, Vol. 14, will be issued about May 1st. The credit for this result belongs to your Secretary, your Committee on Publications and to your Editor, Prof. W. D. Pence.

The American Railway Association have made the following appropriations on account of the investigations of the Rail Committee: In 1910, $5,000; 1911, $6,000; 1912, $10,000; total, $21,000; and in November, 1912, a further appropriation of $10,000 was made for the work of 1913, bringing the total up to $31,000. Against this appropriation there had been expended up to November, 1912, $21,011.41.

Attention is called to the valuable work of the Standing and Special Committees during the year as evidenced by their careful reports, and commendation is due to the various chairmen and committee members.

The Association was invited to be represented at the Fourth National Conservation Congress held at Indianapolis in September, 1912. Messrs. McNab, W. G. Atwood, Ferriday, Fisk and R. C. Young were appointed as delegates to attend that congress.

As the years pass along it becomes also necessary to record the names of those members who have completed their work, the death of whom has deprived our Association of their aid. We have thus lost during the year F. H. Bainbridge, formerly Resident Engineer of the

Chicago & Northwestern Railway, who was a well-known Bridge Engineer, and was a valued member of our Committee on Wooden Bridges and Trestles; D. D. Colvin, Engineer Maintenance of Way of the National Railways of Mexico, who was at one time connected with the Panama Canal Construction before entering railway service in Mexico; and J. C. Young, Signal Engineer of the Union Pacific Railroad, a valued member of the Committee on Signals and Interlocking.

THE ASSOCIATION'S WORK—PAST AND FUTURE.

With the completion of another year in the existence of the American Railway Engineering Association, it is well to review its accomplishments and to point out the work before it.

Its first notable accomplishment has been: The standardization of materials, designs, specifications and records used in the construction and maintenance of the various parts of a railway.

Second—Progress has been made in the specifications governing the making of such complex materials (so largely used by railways) as concrete and steel.

While the first of these items relates almost wholly to materials, the proper use of these materials is largely dependent upon labor, skillfully and economically directed; and the second item—namely, the manufacture of such materials as concrete and steel, is very greatly dependent upon the quality of the labor and upon the honest and thorough use of it.

This Association has had before its committees instances of the short life of concrete, due more often to faulty or dishonest labor used, than to the materials themselves composing it; yet so far, more concern has been given by this Association to the materials than to the labor. The discovery of voids in concrete, or of portions where adhesion is lacking, or again of the misuse or damage by laborers of reinforcing materials, has resulted in the gradual increase in the amount of skilled labor and of supervision employed; because, after all, a mass of concrete is only as strong as its weakest part.

Hence, a record of the very best means of economically constructing and supervising this product seems important at this time.

The manufacture of steel likewise demands employment of skilled labor in every step of the process.

The time was when certain ores of generally known quality when handled and reduced to steel by a method in general practice was all that was necessary; and the product received its name and often its rated value from the record of the individual manufacturers. That time is gone. Labor used instead of being small in numbers is both large and changeable. So, skillful labor and the efficient use of it, as well as of the extensive mechanisms under its control, is the only surety for a steel that will be uniform in good quality.

The Rail Committee of this Association has brought out this point very forcibly to railway people and to the manufacturers of rail, as well as to the public.

It has been found that it is those mills which have sought for scientific care on the part of their men, and which have discharged others for carelessness, or for a misguided loyalty to their employer in their effort to produce quantity at the risk of slighting quality, that are to-day producing rails of the more uniform grade. It is by this method of extreme watchfulness that further improvement will be obtained.

The Rail Committee has shown so far:

First—That while rail failures in the past have had as many explanations as there were manufacturers, with no means of proving or disproving any of them, we now know the general causes, and the remedies are being worked upon.

Second—Many negative results of the investigations prove that good or bad mill work produces good or bad rails, and in many cases overcome the advantages or disadvantages of any particular rail section.

Third—That the amount of discard from the top of ingots does not set a gage on either the high standard of the rail produced, or on the number of rail failures; but rather indicates the relative skill of some mills in controlling the chemical content, casting ingots and rolling rails.

Fourth—That some mills continuously produce better or more uniform material than others; and that this uniformity is largely the result of greater care and skill at the mills, which has been considerably developed by the publications of this Association.

Fifth—And now we are finding that the use of thick base rails of the A. R. A. "B" type is reducing base failures to an insignificant number; and also that care in handling and using rails is productive of both longevity and safety. In fact, that careful labor should follow the treatment of rails until they are removed from main tracks.

To explain one type of watchful labor in detail: About two years ago a broken wheel nicked the rails of over a mile of track on an important railway. These nicked rails began to break under following trains before their replacement could be completed. It seems important, therefore, that track supervisors should promptly remove rails nicked by broken wheels whenever discovered in main tracks.

It is proper here to place on record the fact that Mr. James E. Howard, of the United States Bureau of Standards, has personally complimented the work of this Association on the subject of rails, and it seems well also to call your attention to a recent report of the National Association of Railway Commissioners, by its Special Committee, to whom was assigned the question of Equipment and Rails. In this report many quotations are included from the Proceedings of the American Railway Engineering Association, and the following statement is made:

"The best general information obtainable on the subject for the country as a whole will be found in the reports of the Rail Committee of the American Railway Engineering Association. The care which has been used in obtaining statistics of rail failures by this Committee, in analyzing these figures, and in fearlessly reporting its conclusions, justifies high praise."

It is certainly clear from what has been stated on this subject of rails, that human care and skill will furnish the measure of future beneficial results. In all important successes I have known, the concentration of many minds upon the subject in hand has brought about that happy conclusion.

This problem is a complex and difficult one, but its solution is approaching; and very fortunate will be that mill, or group of mills, that first prove that they are delivering tougher and more uniform rails than are now produced.

As stated in the beginning of these remarks, there is a vast amount of labor employed directly by railways in carrying out the standard specifications and methods that have been approved by this Association. Your committees have this year been requested to note and to report on this matter. This important study is therefore started, as will be seen from the reports of some of the committees.

This Association should keep up to date in labor-saving machinery and devices, and should discover and compile records of the best practice in handling labor with and without their use. It should also refer to its quality and the economical seasons for its employment, as well as to its best supervision in all branches of railway construction, maintenance and operation.

One of the best ways for securing efficient results from labor is to freely recognize any improvement that its intelligent use produces. An employer that always points out the fault only, without commending the gain, soon discourages even the most skilled of artizans. Humanity in general needs incentive and encouragement in addition to wages.

I think you and I can recall instances from school or college days when a simple word of incentive or commendation formed a turning point in our lives on some specific subject. Which is better for a teacher to say, "John, you are behind badly—you failed in two problems"; or, "John, you solved eighteen out of twenty of the problems given—you can succeed with the others also"?

Those of us who have handled tunnel work under old as well as new methods of machinery and labor, know how under the old method the darkey drill force was kept together and made to turn out 50 per cent. more work than any other kind of labor through the incentive song of their leader.

We, in America, have made great strides in methods of getting work done; but we cannot afford to overlook the song of the leader of the boat crew on the Mediterranean who keeps the men at vigorous stroke by his frequent exclamation "Glory to Allah." These are both examples of good "team work."

Some railways adopt a prize system in one or more branches of service. There is no single department that will answer more readily to this system than the labor employed upon the maintenance of track.

Many railways have used this system for years. The Pennsylvania Railroad, for example, has a Special Committee of Maintenance of Way

officers to look after the award of premiums for the maintenance of track and roadbed, which award is finally made after an annual inspection of the road by a large number of its operating officers.

The road with which I am connected has used this plan in a modified form for a long period. Its annual inspection awards upon 2,000 miles of railway last year cost for prizes less than $1,500. This, however, was not a track inspection by officials, but one of Roadmasters and Track Foremen taken from one district to inspect quite another. Not only have these awards been just, but each individual has learned many of the good points found on the other district. Such an inspection is a method of indirect but very effective instruction.

There is an economic cost for putting a new tie in place in the track of every district of a railway, likewise a corresponding one for putting bridge timbers or steel in place, for laying stone masonry, or depositing concrete. The distribution among the districts of each railway of the costs secured each month is a great incentive itself in track and other classes of maintenance labor, as also in other departments of railway service.

If we, for a moment, turn back a dozen years and see how little standardization there existed on railways as a whole, and how little general information was distributed; and compare that with the mass of valuable information in our Manual and Proceedings, we may realize that there must be likewise a large amount of data as to labor and mechanical appliances for cheapening the use and handling of materials that may be compiled in the same manner. This is of special importance, as the unit cost of labor is increasing very rapidly.

The changes in ideas and methods in this branch of economy will be frequent and often great from year to year. Committees can never expect, therefore, to complete this subject. They will, when fully organized in collecting this kind of data, have some new economies to report each year in every branch of the service.

The study of this line of economies often leads to what at first thought appears to be bold undertakings.

As examples to be mentioned because of personal knowledge of the details:

The Norfolk & Western Railway has just successfully swung, under the method of cantilever erection, the central and last through span, 520 ft. long, being one of a total of five double-tracked spans of bridge forming its crossing of the Ohio River. These spans were built around the old spans and rest on the original masonry. The original spans carried the dense traffic until they were replaced. The considerations that led to this novel construction were economy in time and labor combined with the least delays to railway traffic and none to river traffic.

Another study on similar lines of economy of labor and efficiency mostly, which has been under progress in the Engineering Department of the same road since 1905, has just culminated in the undertaking of electrification of twenty-seven miles of that portion of its line having

the steepest grades and densest business in the heart of the Pocahontas coal field, purely for handling freight traffic most economically.

We should always bear in mind that any saving in cost of labor applying materials is net income to a railway, just the same as is the saving in overtime charges in handling trains gained either through improvements in grades or in motive power, or through efficient block signals.

In traveling about over various railway lines, I have observed forces of men employed thereon that do not seem to differ much in number; but there was noticed at the same time a difference in the appearance of the railways, even to the extent of a large percentage. Close investigations of both the labor employed and the business handled will in many cases reveal the fact that for the corresponding amount of traffic the best appearing railway accomplished its maintenance work at the lower cost. The explanation is simply that if is just as easy and no more expensive to work to a definite line or plan than to a random one; and if this method is followed uniformly on every district of a railway, any given standard can be acquired without cost.

One of the leading officials of a great concern was heard sometime ago to say, "We have let one-fourth of our men go; the other three-fourths have since gotten busy, and we are securing great results." While this did not speak well for the past of that concern, it also proved the fact that there were a large number of unproductive employes, who, if they had been always well-directed, would have added greatly to the stability and value of that property.

A number of years ago we had occasion to have railway ties condemned as first-class because they were of variable lengths and presented a bad appearance in track. Many have been satisfied to condemn only when too short. But I submit it is just as easy to have them cut by the makers practically to the right length.

These illustrations show how we can make our permanent way and track in a period of years things of strength, safety and beauty through uniformity acquired without cost except in the time of skillful directors and in the abundance of standard plans and constructive forms economically followed.

Gentlemen, this is part of our work. We are directors of the economical and efficient expenditure of money. We should hesitate to ask for more till we have shown that we are using that in hand to the best advantage; or until we can prove that we can secure a fair percentage of earning from the additional amount requested.

The American Railway Engineering Association can aid in the development of skill in labor efficiency just as it has developed and must continue to improve the standards of materials and specifications. (Applause.)

The next business is the reading of the Secretary's report and the Treasurer's report.

Secretary E. H. Fritch then read the following reports:

SECRETARY'S REPORT.

To the Members of the American Railway Engineering Association:

I have the honor to present the following report for the calendar year ending December 31, 1912:

MEMBERSHIP.

Total membership December 31, 1911		1,004
Additions during the year		102
		1,106
Deceased members	5	
Withdrawals during the year	12	
Dropped for non-payment of dues	23	
	—	40
Total membership December 31, 1912		1,066

GEOGRAPHICAL DISTRIBUTION.

The geographical distribution of the membership is indicated in the following table:

United States	925	Philippine Islands	2
Dominion of Canada	91	Australia	1
Japan	8	Bolivia	1
China	7	Brazil	1
Mexico	6	Korea	1
Cuba	5	Panama	1
Central America	4	Porto Rico	1
New Zealand	4	Russia	1
Argentine Republic	2	Uruguay	1
Great Britain	2		
Peru	2	Total	1,066

CLASSIFICATION OF MEMBERS.

Presidents	26	Locating Engineers	5
Assistants to Presidents	8	Engineers Track and Roadway	10
Vice-Presidents	29	Office Engineers	10
General Managers	17	Chief Draftsmen	4
Director Maint. and Operation	1	Roadmasters	17
Asst. General Managers	10	Supt. Bridges and Buildings	15
General Superintendents	15	Supervisors	3
Asst. Gen. Superintendents	2	Resident Engineers	31
Division Superintendents	42	Signal Engineers	17
Chief Engineers	127	Managers Timber Department	10
Asst. Chief Engineers	24	Contracting Engineers	19
Principal Assistant Engineers	17	Chemists and Engrs. of Tests	11
Chief Eng. Maint. of Way	5	Professors in Colleges	25
Asst. Chief Engrs. M. of Way	2	Associate Professors	18
Engineers of Construction	19	Civil Engineers	37
Engineers Maint. of Way	80	Consulting Engineers	95
Bridge Engineers	36	Engineers Grade Elimination	4
Division Engineers	81	Editors	4
Assistant Engineers	110	Valuation Engineers	4
District Engineers	15	Municipal Engineers	8
Electrical Engineers	4	Miscellaneous	27
Inspecting Engineers	17		
Architects	5	Total	1,066

PUBLICATIONS.

During the year the following publications have been issued by the Association:

10 Bulletins.

Proceedings for 1912.

1 Edition of the Supplement to the Manual.

1 Edition of Specifications for Steel Railway Bridges.

1 Edition of Specifications for Overhead Crossings of Electric Light and Power Lines.

1 Edition of Leaflet on Track.

Program of the Thirteenth Annual Convention.

1 Edition of Specifications for Plain and Reinforced Concrete and Steel Reinforcement.

1 Edition of Conventional Signs Leaflet.

12 Rail Report Leaflets.

The table below indicates the number of pages, illustrations, etc., of the publications issued:

	No. Pages	Half-Tones	Folding Plates	Diagrams	Tables	Forms
Bulletins	1,542	210	14	178	394	6
Proceedings	1,364	334	14	296	171	...
Conventional Signs	16	...	...	...	...	...
Concrete Specifications	16	...	...	...	...	...
Overhead Crossings Specifications	16	...	...	...	...	...
Steel Specifications	36	...	...	...	...	...
Track Leaflet	44	...	...	...	...	...
Program	56	...	...	...	...	...
Supplement to Manual	136	44	...	14	4	...
	3,226	588	28	488	569	6

Vol. 14, Proceedings for 1912, containing 1,364 pages, was the first volume issued under the new method, and was completed by May 1st, forty days after the adjournment of the convention of 1912. The many advantages and economies resulting from the present method have fully justified its adoption for the publication of the Proceedings.

FINANCIAL STATEMENT.

Balance on hand December 31, 1911		$ 7,562.15
Consisting of:		
Six railway bonds	$ 5,206.06	
Cash in bank	2,356.09	
Receipts during the year 1912:		
From members	$13,363.25	
From others—sales of publications, advertising, etc.	6,111.19	
From American Railway Association, Rail Committee fund	7,961.81	
From interest on bank balance	123.66	
From interest on investments	280.00	
Total receipts in 1912	$27,839.91	

SUMMARY.

Receipts during 1912		$27,839.91	
Expenditures:			
December 1911 vouchers, paid January 4, 1912	$ 1,047.68		
Vouchers for 1912	23,609.12	24,656.80	
Excess of receipts over expenditures		$ 3,183.11	3,183.11
Assets December 31, 1912			$10,745.26
Consisting of:			
Six railway bonds		$ 5,206.06	
Cash in bank		5,539.20	
		$10,745.26	

EXPENDITURES FOR 1912 IN DETAIL.

Stationery and printing	$ 501.61
Proceedings	3,001.84
Bulletins	3,593.38
Postage	888.74
Salaries	4,196.54
Expressage	323.68
Exchange	26.55
Committee expenses	88.06
Rents	846.64
Light	26.31
Equipment	220.70
Officers' expenses	37.90
Supplies	369.26
Annual meeting	962.29
Phone and Telegrams	107.65
Miscellaneous	282.50
Manual	72.46
Impact tests	101.20
Rail Committee expenses	7,961.81
Total	$23,609.12

Respectfully submitted,

E. H. FRITCH, *Secretary.*

TREASURER'S REPORT.

To the Members of the American Railway Engineering Association:

I have the honor of presenting the following report for the calendar year ending December 31, 1912:

Balance cash on hand December 31, 1911		$ 7,562.15
Consisting of:		
Cash in bank	$ 2,356.09	
Six railway bonds, at cost	5,206.06	
	$ 7,562.15	
Receipts during the year 1912	$27,839.91	
Paid out on audited vouchers:		
December (1911) vouchers	$ 1,047.68	
Vouchers for 1912	23,609.12	
Total withdrawals	$24,656.80	24,656.80
Excess of receipts over disbursements	$ 3,183.11	3,183.11
Balance on hand December 31, 1912		$10,745.26

Consisting of:

Cash in Standard Trust and Savings Bank	$ 5,539.20
Six railway bonds, par value $1,000 each, at cost	5,206.06
Total	$10,745.26

The six railway bonds are registered in the name of the Association and are in a safety deposit box in the Merchants Loan and Trust Company's vaults, Chicago.

Respectfully submitted,

GEO. H. BREMNER, *Treasurer.*

The Secretary:—The accounts have been audited by Public Accountants, and their figures agree with the foregoing.

(Upon motion, duly carried, the reports of the Secretary and Treasurer were accepted.)

The President:—The Chair desires to call to the attention of the members the importance of registering promptly, and also to arrange for their tickets to the annual dinner. There is a considerable demand for tickets this year. The dinner, as you will note by the program, is scheduled for Wednesday evening. This evening at eight o'clock there is to be a reception by the Board of Direction, and it is hoped that all members, with their ladies, will be present. This function is somewhat different from what has been followed in the past, and we want to make it a success. We think it will bring about some desirable social features.

The next order of business is the reports of Standing and Special Committees. The first Committee is that on Rules and Organization. In the absence of the Chairman of the Committee, Mr. Jos. O. Osgood, the Vice-Chairman, Mr. G. D. Brooke, will present the report.

(The report of the Committee on Rules and Organization was presented by the Vice-Chairman, Mr. G. D. Brooke, Superintendent, Baltimore & Ohio Railroad. See report, pp. 65-70; discussion, pp. 1021-1045.)

The President:—The next report is that of the Committee on Signals and Interlocking. The report will be presented by the Chairman, Mr. A. H. Rudd.

(The report of the Committee on Signals and Interlocking was presented by the Chairman, Mr. A. H. Rudd, Signal Engineer, Pennsylvania Railroad. See report, pp. 71-80; discussion, page 1046.)

AFTERNOON SESSION.

The President:—The first business which we will take up is the report of the Committee on Iron and Steel Structures, of which Mr. A. J. Himes is Chairman.

(The report of the Committee on Iron and Steel Structures was presented by the Chairman, Mr. A. J. Himes, Engineer of Grade Elimination, New York, Chicago & St. Louis Railroad. See report, pp. 81-96; discussion, pp. 1047-1057.)

The next report on the program is that of the Committee on Track, Mr. J. B. Jenkins, Chairman.

(The report of the Committee on Track was presented by the Chairman, Mr. J. B. Jenkins, Assistant Engineer, Baltimore & Ohio Railroad. See report, pp. 97-131; discussion, pp. 1058-1068.)

The President:—We will next take up the report of the Committee on Rail, which will be presented by Mr. W. C. Cushing, the Chairman.

(The report of the Committee on Rail was presented by the Chairman, Mr. W. C. Cushing, Chief Engineer Maintenance of Way, Southwest System, Pennsylvania Lines West of Pittsburgh. See report, pp. 169-578; discussion, pp. 1103-1107.)

(Adjournment until 9 o'clock Wednesday morning.)

WEDNESDAY, MARCH 19, 1913.

MORNING SESSION.

The President:—You will note from the program that it has been considered desirable by the Committee on Arrangements that one day be set aside for visiting the admirable exhibit of the National Railway Appliances Association at the Coliseum and Armory, and that day is Friday, the 21st. Of course, we cannot tell how long our sessions will hold, but no doubt there will be some available time during the convention at the disposal of the members to enable those who cannot remain over until Friday to visit the exhibits.

The Committee on Arrangements requests that announcement be made that the annual dinner will be held this evening. A considerable demand for tickets has developed, and the Committee asks that members who have not yet secured tickets to that function secure them during the noon recess.

The first business to be transacted this morning is the consideration of the report of the Committee on Economics of Railway Location, of which Mr. A. K. Shurtleff is Chairman.

(The report of the Committee on Economics of Railway Location was presented by the Chairman, Mr. A. K. Shurtleff, Office Engineer, Chicago, Rock Island & Pacific Railway. See report, pp. 579-651; discussion, pp. 1108-1135.)

The President:—We will next take up the report of the Committee on Wooden Bridges and Trestles, Mr. I. L. Simmons, Chairman.

(The report of the Committee on Wooden Bridges and Trestles was presented by the Chairman, Mr. I. L. Simmons, Bridge Engineer, Chicago, Rock Island & Pacific Railway. See report, pp. 652-697; discussion, pp. 1136-1143.)

The President:—Before we adjourn, the Chair desires to announce that the polls for election of officers for the coming year will be closed at noon to-day. The Chair would appoint the following Tellers to count the ballots and make their report so that the result of the election can be announced at the close of the afternoon session on Wednesday: C. H. Spencer, Chairman; C. H. Fisk, W. J. Bergen, J. C. Nelson, H. L. Gordon, E. A. Frink. The Secretary will turn over the ballots to the Tellers at the close of the morning session and the Tellers will retire to count the votes cast.

AFTERNOON SESSION.

The first report this afternoon is that of the Special Committee on Uniform General Contract Forms, Mr. Wm. G. Atwood, Chairman.

(The report of the Special Committee on Uniform General Contract Forms was presented by the Chairman, Mr. Wm. G. Atwood, Chief Engineer, Lake Erie & Western Railroad. See report, pp. 699-709; discussion, pp. 1144-1164.)

The President:—The report of the Committee on Wood Preservation is next in order, and will be presented by the Chairman, Mr. Earl Stimson.

(The report of the Committee on Wood Preservation was presented by the Chairman, Mr. Earl Stimson, Engineer Maintenance of Way, Baltimore & Ohio Railroad. See report, pp. 711-726; discussion, pp. 1165, 1166.)

The President:—We will next take up the report of the Committee on Ties. The report will be submitted by the Chairman, Mr. L. A. Downs.

(The report of the Committee on Ties was presented by the Chairman, Mr. L. A. Downs, Superintendent, Illinois Central Railroad. See report, pp. 727-790; discussion, pp. 1167-1170.)

The President:—We will next consider the report of the Committee on Signs, Fences and Crossings, Mr. C. H. Stein, Chairman.

(The report of the Committee on Signs, Fences and Crossings was presented by the Chairman, Mr. C. H. Stein, Engineer Maintenance of Way, Central Railroad of New Jersey. See report, pp. 791-830; discussion, pp. 1171-1178.)

The President:—The next report to be considered is that of the Committee on Masonry. In the absence of the Chairman, Mr. G. H. Tinker, the Vice-Chairman, Mr. F. L. Thompson, will present the report.

(The report of the Committee on Masonry was presented by the Vice-Chairman, Mr. F. L. Thompson, Engineer Bridges and Buildings, Illinois Central Railroad. See report, pp. 831-838; discussion, page 1179.)

The President:—Before we adjourn, the Chair requests unanimous consent to vary from the printed program and advance two reports out of the printed order. This change is made necessary on account of the departure in the early afternoon of some members of the two committees. If there is no objection, we will take up in the morning session the reports of the Committees on Yards and Terminals and Electricity; the remainder of the schedule to be followed as printed in the program.

The Secretary will read the report of the Tellers, appointed to canvass the votes for officers for the coming year.

The Secretary:—The report of the tellers is as follows:

REPORT OF TELLERS.

To the Members of the American Railway Engineering Association:

Your Committee, appointed to canvass the votes cast for the election of officers, Board of Direction and Nominating Committee for the ensuing year, beg to advise that after careful examination and canvass of each ballot, we find the result to be as follows:

Total vote cast	632
Not counted on account of being unsigned	11
Total vote counted	621

PRESIDENT:

Edwin F. Wendt	613
C. F. Loweth	2
J. B. Berry	2
A. W. Thompson	1
Robert Trimble	1
Geo. H. Webb	1
W. B. Storey, Jr.	1

VICE-PRESIDENT:

Robert Trimble	618
J. B. Berry	1
A. H. Rudd	1
Edwin F. Wendt	1

TREASURER:

Geo. H. Bremner	621

SECRETARY:

E. H. Fritch	621

DIRECTORS:

A. K. Shurtleff	314
C. A. Morse	256
John G. Sullivan	225
Earl Stimson	209
H. S. Balliet	188
C. H. Ewing	183
John V. Hanna	173
John D. Isaacs	165
C. E. Lindsay	109
H. T. Douglas, Jr.	1

NOMINATING COMMITTEE:

H. R. Safford	400
A. O. Cunningham	366
R. L. Huntley	345
R. N. Begien	337
A. F. Robinson	331
E. H. Lee	279
H. E. Hale	254
W. M. Dawley	250
J. B. Jenkins	225
C. A. Wilson	165
J. M. Brown	1
E. R. Lewis	1
L. C. Fritch	1

Respectfully submitted,

C. H. SPENCER, *Chairman;*
W. J. BERGEN,
C. H. FISK,
E. A. FRINK,
H. L. GORDON,
J. C. NELSON,
Tellers.

The Secretary:—The result of the ballot for officers is as follows:
President—Edwin F. Wendt.
Vice-President—Robert Trimble.
Treasurer—Geo. H. Bremner.
Secretary—E. H. Fritch.
Three Directors (three years each)—A. K. Shurtleff, C. A. Morse, John G. Sullivan.
Five Members of Nominating Committee—H. R. Safford, A. O. Cunningham, R. L. Huntley, R. N. Begien, A. F. Robinson.
(Adjournment until 9 o'clock Thursday morning.)

THURSDAY, MARCH 20, 1913.

MORNING SESSION.

The President:—In accordance with the action taken yesterday afternoon, we will first consider the report of the Committee on Yards and Terminals, Mr. C. H. Spencer, Chairman.

(The report of the Committee on Yards and Terminals was presented by the Chairman, Mr. C. H. Spencer, Engineer, Washington Terminal Company. See report, pp. 913-954; discussion, pp. 1089-1100.)

The President:—The next report to be considered is that of the Committee on Electricity, Mr. George W. Kittredge, Chairman.

(The report of the Committee on Electricity was presented by the Chairman, Mr. George W. Kittredge, Chief Engineer, New York Central & Hudson River Railroad. See report, pp. 987-1012; discussion, page 1180.)

The President:—The report of the Committee on Conservation of Natural Resources will be presented by the Chairman, Mr. William McNab.

(The report of the Committee on Conservation of Natural Resources was presented by the Chairman, Mr. William McNab, Principal Assistant Engineer, Grand Trunk Railway System. See report, pp. 133-143; discussion, pp. 1069-1076.)

The President:—The Chair wishes to make a statement in regard to the attendance at this Convention, particularly with reference to the attendance at this morning's session, compared with the corresponding sessions of last year and of the year before. The figures are as follows:

Members registered Thursday morning, 1911.....351
Members registered Thursday morning, 1912.....386
Members registered Thursday morning, 1913.....421

The Chair also desires to announce that Prof. W. K. Hatt of Purdue University will deliver a lecture in this room to-night at 7:30 o'clock on tests on rerolled steel rails for reinforced concrete bars. All members and guests are invited to be present.

We will now consider the report of the Committee on Ballast, and it will be presented by the Chairman, Mr. H. E. Hale.

(The report of the Committee on Ballast was presented by the Chairman, Mr. H. E. Hale, Engineer of Maintenance, Missouri Pacific Railway. See report, pp. 144-168; discussion, pp. 1077-1083.)

The President:—The next report to be considered is that of the Committee on Buildings, Mr. Maurice Coburn, Chairman.

(The report of the Committee on Buildings was presented by the Chairman, Mr. Maurice Coburn, Principal Assistant Engineer, Vandalia Railroad. See report, pp. 839-880; discussion, pp. 1084-1086.)

The President:—The report of the Committee on Water Service will be presented by the Chairman, Mr. Robert Ferriday.

(The report of the Committee on Water Service was presented by the Chairman, Mr. Robert Ferriday, Engineer Maintenance of Way, Cleveland, Cincinnati, Chicago & St. Louis Railway. See report, pp. 881-912; discussion, pp. 1087, 1088.)

The President:—Dr. Hermann von Schrenk, the Chairman of the Special Committee on Grading of Lumber, will present the report of that Committee.

(The report of the Special Committee on Grading of Lumber was presented by the Chairman, Dr. Hermann von Schrenk, Consulting Timber Engineer, New York Central Lines, Chicago, Rock Island & Pacific and 'Frisco Lines. See report, pp. 955, 956; discussion, page 1101.)

The President:—The next report to be taken up for consideration is that of the Committee on Roadway, Mr. W. M. Dawley, Chairman.

(The report of the Committee on Roadway was presented by the Chairman, Mr. W. M. Dawley, Assistant Engineer, Erie Railroad. See report, pp. 957-986; discussion, page 1102.)

The President:—The last report to be considered is that of the Committee on Records and Accounts. Is the Committee present? The members of the Committee do not seem to be in the room.

Mr. George W. Kittredge (New York Central & Hudson River Railroad):—In the absence of the Committee, I move that the report be read by title and printed in the Proceedings.

Mr. L. C. Fritch (Chicago Great Western):—I second the motion.

The President:—Unless there is objection, the motion will be considered adopted and the course suggested will be followed. The report is received as information.

The reports of the Standing and Special Committees having been disposed of, the Secretary will read some resolutions he has prepared:

Secretary Fritch:—Mr. President, I desire to offer the following resolutions:

"*Resolved,* by the members of the American Railway Engineering Association, in convention assembled, that we desire to place on record our appreciation and extend our hearty thanks to the following:

"To Mr. B. A. Worthington, Rev. R. W. Dickie, Mr. Geo. A. Post and Mr. P. G. Rennick, for their admirable and instructive addresses at our annual dinner; to the National Railway Appliances Association, for courtesies extended to the members of the Association, and

for the valuable and interesting exhibit of railway devices used in the construction, operation and maintenance of railways; to the technical press for their daily reports of the convention and useful information made available to the members; to the official reporters, Messrs. T. E. Crossman and G. W. Burgoyne, for their accurate and painstaking reports of the proceedings of this and previous conventions; to the Tellers for their arduous labors in counting and tabulating the ballots for officers for the current year; to Committee No. "23," on Arrangements, for the highly successful arrangements made for the comfort and entertainment of the members and guests attending this convention, and it is recommended to the Board to 'increase the Committee's salary' for the coming year."

Mr. L. C. Fritch (Chicago Great Western):—I move that these resolutions be adopted by a unanimous and a rising vote.

Mr. George W. Kittredge (New York Central & Hudson River Railroad):—I second the motion.

(Motion carried unanimously, with applause.)

Mr. Kittredge:—I desire to offer the following resolution:

"*Resolved,* by the members of the American Railway Engineering Association, in convention assembled, that we desire to and hereby do give an expression of appreciation of the able manner in which the retiring President, Mr. Chas. S. Churchill, has discharged the duties of President during the past year and presided over the meetings of this convention; that this resolution be spread upon the Minutes and a copy be furnished to Mr. Churchill." (Applause.)

Mr. L. C. Fritch:—I move that this resolution be adopted, that it be made unanimous, and that the vote be a rising vote.

(Motion seconded and the resolution was unanimously adopted amid applause.)

The President:—I thank you very much, gentlemen, for your kind expressions. As one of the ancient members of this Association, I enjoy appreciation of this kind. I consider it an honor to have had this position. I wish success to my successor. I know he will have it, because in this Association every officer has the hearty support of all the members. That is one peculiarity of this Association above all others with which I am acquainted. This is a working organization; it has the respect and esteem of the whole of the United States. It is growing in power and in the results accomplished by it daily; and it is all by the cooperation, by the frank discussion, by turning down mistakes that are made that are clearly mistakes, and by making corrections promptly; in that way we will keep up with the times, and that is what we are trying to do as railroad people. We must be alive, up-to-date, and must take up the new questions that have been suggested and follow them out to the limit. I thank you, gentlemen. (Applause.)

The President:—The Chair will ask Mr. L. C. Fritch and Mr. George W. Kittredge to escort the new President to the Chair. (Applause.)

President-Elect Edwin F. Wendt then addressed the convention as follows:

President Wendt:—Fellow-Members of the American Railway Engineering Association: I deeply appreciate the honor which you have conferred upon me, and it will be my purpose to endeavor faithfully to discharge the duties of the Presidency in a manner to merit the confidence which you have placed in me.

The record of the past is the only safe guide for the future. We know that our Association during its first fourteen years, which have now been completed, has been successful. Nevertheless, as one writer has said, "However glorious the past may have been, we would not live it over again even if we could." The present is exactly what we make it, but it is of the future that we would speak. With your cooperation, the work of this Association during the coming year will be carried on successfully.

This success will be the result of the cooperation of the various elements in our organization, some of which are:

(1) We have an efficient Secretary, Mr. E. H. Fritch, who has just been re-elected by a unanimous vote. He will be with us next year—however, at an increased salary. (Applause.) The Board of Direction has thus recognized his faithful service. Great credit is due Mr. Fritch for the able, intelligent and efficient manner in which he conducts the work of the Chicago office.

(2) The Entertainment Committee, Mr. Frank Coates, Chairman, has been so successful as to have earned what will probably be "life tenure of office." (Laughter.) This Committee is entitled to our gratitude for the success of the banquet of last evening. The entertainment was fully up to the standard of our Association, and we will request the Committee to get busy at once with respect to the banquet of 1914, so that it may, if possible, be equally successful. The Entertainment Committee consists of members who are experts in all matters pertaining to the organization of a successful banquet and they are entitled to our thanks, especially as their work is gratuitous for the benefit of the Association.

(3) As a railway business organization, we feel justified in congratulating ourselves upon having with us year after year two such skilful and faithful stenographers as Messrs. T. E. Crossman and G. W. Burgoyne, who have so efficiently served the Association during the past thirteen years. These gentlemen are practically Associate Members.

(4) I feel that we are justified in supplementing the formal resolution which has just been passed by a further statement of the value of

the exhibition at the Coliseum, under the direction of the National Railway Appliances Association. I had the pleasure yesterday, in company with the President of that Association, of inspecting the entire exhibition, and learned with much satisfaction that the attendance at this exhibition, during the week of our convention, is fully fifty thousand. The attendance shows that the railroads appreciate the great value of the exhibition. Many railroads have arranged for large numbers of their men in the Track, Bridge, Building and Signal Departments to attend this exhibition. Some railroads are sending their Roadmasters for a distance of one thousand miles.

It is interesting to know that one Division Engineer organized his Supervisors and Section Foremen so that different groups would attend on different days, each group being in charge of a leader who was expected upon his return home to make a written report to the Division Engineer, containing suggestions as to improved machinery. This plan might be followed with profit by many railroads.

The direct expense of the exhibition, according to the statement of the President, is about Twenty-seven Thousand Dollars ($27,000.00) per year, and the capital represented by the exhibition is about Four Hundred Ninety-five Million Dollars ($495,000,000.00).

It is a pleasure to know that, while the two associations are separate and have no official connection, yet there is a spirit of cooperation between the American Railway Engineering Association and the National Railway Appliances Association. Each association has a distinct and separate work, but we are both striving for higher standards.

(5) We are especially fortunate in having as an aid to the work of our Association the technical press, and it is a pleasure to acknowledge the value and excellence of their publications which are issued in connection with the work of our Association. We have in the past never failed to compliment the technical press and the tribute which we pay year by year to the editors is justly deserved. We should congratulate ourselves because we enjoy the confidence and cooperation of the technical press.

(6) The committees of our Association are responsible for the direct tangible results which finally appear in the Manual. Without the help of the twenty standing committees we would accomplish but little, and I say with confidence that the thorough work which is done by the committees is that which receives the greatest approbation of the general membership.

(7) During the past five years I have been a member of the Board of Direction, and I wish to acknowledge that it has been a great pleasure to attend the meetings of the Board and to cooperate with the members in handling the work of the Association.

The Board of Direction is composed of nineteen men—very busy men; men who live at points far distant from Chicago, such as Winnipeg and Montreal on the north; New York and Roanoke on the east; Nash-

ville and San Antonio on the south, and Omaha on the west. These men, however, busy as they are, are so interested in the work of the Association as to make it a point to arrange their business so that they can attend the meetings of the Board. Too much credit cannot be given to the members of the Board for their faithful work. It has been a great pleasure to me to associate with the Board during the past few years. I violate no confidence in saying that the Board of Direction is conservatively optimistic with respect to the future work and success of our Association. The policy of the Board has always been "Unity in Essentials," "Liberty in Non-essentials" and "A broad charity toward present standards." We favor the greatest liberty of discussion and freedom of opinion. The object of our Association will be attained through "Evolution, not Revolution."

I wish to say a few words respecting an increase in our membership. In order to accomplish more work our Association needs more money. The easiest way and the natural way to get more money is through a larger membership. On January 1, 1913, our membership was 1,066. Today we are pleased to report a membership of 1,115.

However, our opinion is that there are from 1,500 to 2,000 railway men in America who ought to be members of our Association. They should be members because they can do the Association much good and, on the other hand, the Association can confer on them an equal benefit. We urge our present membership to put forth greater efforts in the coming year to attract new members, because an increased membership means more revenue and more revenue will enable us to prosecute our work with greater rapidity.

The object of this Association is "The advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways." The results of this scientific study will be of very great benefit to ourselves and to the railways with which we are associated. The railway problem should be studied systematically in order that we should escape many troubles of the school of experience, because, as Benjamin Franklin said, "Experience keeps a dear school, but fools will learn in no other and sometimes scarcely in that."

If we follow the object of the Association and pursue the scientific study of those difficult problems which now confront us and temper theory with experience, we will accomplish that which was the intention of the framers of the Constitution of our organization.

The American Railway Engineering Association was born and organized in the tranquil days which characterized the opening of the Twentieth Century. Since that time, however, public opinion has demanded some regulation of the railway business and in 1906 Congress passed the Hepburn Act, which increased the powers of the Interstate Commerce Commission so that at the present time our business is subject to reasonable governmental regulation. We must meet these new conditions and I, for one, have no doubt that when our intelligence is directed to the study of scientific principles which underlie the organiza-

tion and success of the railway business we will approve a conservative policy of governmental regulation.

A new problem has now arisen—a gigantic problem we think. Congress passed the Railway Valuation Act on March, 1913, and the Interstate Commerce Commission is charged with the duty of valuing the railways of this country promptly. The results of this work will be of tremendous importance, because of the large amount of capital invested in the business. For several years past, the Board of Direction has discussed the question of the appointment of a special committee to outline a plan for the study of the scientific principles of railway valuation, and a decision will be made respecting this matter in the near future. This work naturally comes within the scope of our Association, because the Constitution requires our membership to work for the advancement of "knowledge" pertaining to the science of the railway business. The economic principles controlling the location, construction, operation and maintenance of railways should be determined by our Association. We have members who are capable to do this work, and it behooves every member of our organization to intelligently direct his energies toward the proper solution of the problem which is now before the country.

We should emphasize the point which was made by several speakers at our banquet last evening, that our membership, which is composed of the highest type of Civil Engineers, should speak freely its mind with respect to the fundamental principles which should govern the determination of the problem of "Railway Valuation," and I venture the prediction that when the railway properties of America are intelligently valued, both the public and the railroad companies will be satisfied with the result.

In conclusion, gentlemen, I thank you again for the distinguished honor which you have conferred upon me, and I assure you of my purpose to endeavor to conduct the work of the Presidency so as to reflect credit on our Association. (Applause.)

Is there any other business to come before this convention? If not, the Chair desires to announce that there will be a meeting of the Board of Direction in room 1166, at 2 o'clock. We desire to meet all of the new Directors whose names have just been announced.

The Fourteenth Annual Convention will now stand adjourned, and we will convene the Fifteenth Annual Convention one year hence, in March, 1914.

E. H. Fritch, *Secretary.*

COMMITTEE REPORTS

REPORT OF COMMITTEE XII—ON RULES AND ORGANIZATION.

Jos. O. Osgood, *Chairman;* G. D. Brooke, *Vice-Chairman;*
F. D. Anthony, J. A. Gordon,
J. B. Carothers, K. H. Hanger,
S. E. Coombs, B. Herman,
J. B. Dickson, Jos. Mullen,
C. Dougherty, E. T. Reisler,
W. T. Eaton, A. F. Stewart,

Committee.

To the Members of the American Railway Engineering Association:

A meeting of the Committee was held in New York on Thursday, November 7, 1912. This meeting was attended by Messrs. Osgood, Chairman; Brooke, Anthony, Carothers, Herman and Reisler.

Communications were received from Messrs. Coombs, Dickson, Dougherty, Hanger, Mullen and Stewart.

Last year's report of the Committee consisted of the presentation of a number of rules in the nature of specificatons or instructions regarding the government of employes and the conduct of work of the Maintenance of Way Department.

The subjects assigned the Committee for this year were to continue the work of last year, as follows:

(1) The compilation of rules for the government of maintenance of way employes, and

(2) The formulation of rules in the nature of specifications or instructions regarding the conduct of work, making use of the recommendations of the various Committees dealing with these subjects and of the best practice of Railway Companies as embodied in their books of rules.

In accordance with the first instruction, the Committee recommends that revisions and additions be made in the General Rules for the Government of Employes of the Maintenance of Way Department heretofore adopted by the Association, as follows:

Revise Rule No. 8 under "Track Supervisors," "Track Foremen," "Supervisors of Structures," "Bridge and Building Foremen," "Signal Supervisors" and "Signal Foremen" to read as follows:

Present Rule.

(8) They shall conform to the prescribed standards and plans in the execution of work under their charge.

Proposed Rule.

(8) They shall conform to the prescribed standards, plans and specifications in the execution of the work under their charge.

Insert under "Track Foremen" a rule to be No. 17 and reading as follows:

They must keep all interlocking pipe lines and trunking free from grass and weeds and all switches, frogs and movable parts of interlocking plants free from snow, ice and other obstructions.

Under "Track Foremen" change Rule No. 17 to be No. 18.

Insert a rule under "Track Supervisors" to be No. 17 and under "Track Foremen" to be No. 19 to read as follows:

Any action proposed by County, Township, Municipal or other authority, which will in any way affect the Company, shall be reported immediately to the ..... (Title) .....

Insert under General Notice rules to be No. 12 and No. 13 and reading as follows:

(12) The use of intoxicants by employes while on duty is prohibited. Their use, or the frequenting of places where they are sold, is sufficient cause for dismissal.

(13) Employes subject to emergency call shall notify their immediate superior officer and the Division Superintendent of any change in address, whether temporary or permanent.

In accordance with the second instruction, the Committee recommends that the following rules be added to the "Instructions" which were presented and adopted by the Association at its convention of last year:

NOTE—In preparing these rules the specifications have been taken wherever possible from the approved recommendations of the other Committees of the Association; the wording only being changed, where necessary, to conform to that of the other rules.

Tie-Plates.

27. Tie-plates must be used wherever ties wear out faster than they fail by ordinary decay. They must be put on so as to get a full and level bearing on the tie and against the rail.

Gaging.

28. Perfect gage is one of the essential features of good track; gage kinks are as detrimental as low joints.

29. The standard gage is 4′ 8½″. Curves eight degrees (8°) and under should be standard gage. Gage should be widened one-eighth inch (⅛″) for each two degrees (2°), or fraction thereof, over eight degrees (8°) to a maximum of four feet nine and one-quarter inches (4′ 9¼″) for tracks of standard gage. Gage, including widening due to wear, should never exceed four feet nine and one-half inches (4′ 9½″).

30. The installation of frogs upon the inside of curves is to be avoided wherever practicable; where this is unavoidable the gage of the track at the frog should be standard.

Curve Easement.

31. On all curves the amount of super-elevation to be given to the outer rail and the proper easement to be provided at the ends shall conform to the standards for "Track" as prescribed by the American Railway Engineering Association and published in the Manual, edition of 1911.

Switches.

32. Switches must be placed in accordance with the standard plans and as located by the Engineer.

33. Switches and frogs must be kept well lined and in good order. Particular care must be taken to maintain good surface at switches.

34. Switches must be inspected frequently to see that they are in working order and that all nuts, bolts and other fastenings are in place and properly tightened. Broken or damaged parts must be renewed promptly.

35. Switch points must fit closely and accurately to the stock rail, which must be bent to suit the angle of the switch. The bend in the stock rail shall be at such distance ahead of the switch point as will make the gage line continuous.

36. Lead rails in all turnouts must be curved with a rail bender before being laid.

37. All main track switches leading to sidings or branch lines should be protected by switch connected derails.

Switch Ties.

38. Switch ties must be used for all permanent turnouts, crossovers and railroad crossings and placed as shown on the standard plans.

Guard Rails.

39. Frogs must be protected by guard rails, constructed and placed in accordance with standard plans. The tops of the guard rails must be level with the tops of the main rails and must be securely held in place.

40. Guard rails must be so placed that the distance from the gage side of the head of the frog wing rail to the flangeway side of the guard rail shall be exactly four feet six and three quarters inches (4′ 6¾″) and great care must be taken to preserve this distance.

Track Posts and Signs.

41. All signal posts, whistle posts, mile posts, signal targets, bridge and other standard signs must be kept plumb and in good condition.

42. Whistle posts must be placed so as not to be obscured by fences or other signs.

Care of Track Tools.

43. Tools must not be left standing within six feet (6′) of the nearest rail of the track on which a train is approaching.

Road Crossings.

44. Road and street crossings must be constructed as shown on the standard plans and kept in good order.

45. Particular care must be taken to remove as far as practicable all obstacles which obstruct the view of crossing signs and approaching trains.

46. Flangeways must be kept clear of rubbish, snow, ice and other obstructions; defective crossing planks must be repaired promptly.

Platforms.

47. Station platforms must be kept clean, free from rubbish, snow and ice, and in good order.

48. Defective platforms must be promptly repaired or reported.

Fences and Cattle-Guards.

49. Fences and gates along the right-of-way shall be kept in repair and all gates kept closed when they are not in actual use.

50. Cattle-guards must be kept in repair and at all times free from dirt, rubbish and other obstructions.

Track Jacks.

51. Track jacks must not be used between the rails of main tracks, except in unavoidable cases; the track must then be properly protected as in the case of other obstructions.

RULES GOVERNING THE USE OF STOP AND CAUTIONARY SIGNALS FOR THE PROTECTION OF UNSAFE AND OBSTRUCTED TRACK.

Flagging.

52. In case of impassable track, flagging is the first duty, and repairs must wait, if necessary, until signals have been placed.

Flagging Before Obstructing Track.

53. The track must never be obstructed without first displaying stop signals not less than twenty (20) telegraph poles in each direction from the point of obstruction. Stop signals must be in the hands of reliable men. Flagmen must stop all trains and explain to the engineman the nature of the obstruction and its exact location.

Slow Orders.

54. When the track is not in condition for the passage of trains at the usual rate of speed, and this condition will continue over night or for the greater portion of a day, notice must be given immediately to the .....(Title)..... In such notices the place of danger, its nature, and the speed at which trains may pass must be stated.

In addition to sending this notice, slow (color) signals must be displayed. When repairs have been made the person making them must at once notify the .....(Title)..... that the slow order may be recalled.

Signals to Be Used.

55. The color, hand, flag, lamp and engine steam whistle signals, and the train markers prescribed by and published in the Standard Code of the American Railway Association shall be used. (It is suggested that copies of the description and rules for the use of these signals, including diagrams, be inserted in books of rules governing maintenance of way employes.)

Time for Obstructing Track.

56. All work which will obstruct the track must be done at such times as will interfere as little as practicable with the passage of trains.

Obstructing Track in Storm or Fog.

57. Except in case of emergency, no work that will obstruct the track shall be done during fogs or storms.

Signals in Obscure Weather.

58. In obscure weather, or on heavy grades or curves, extraordinary care must be taken to make sure that the stop signals are out a sufficient distance in both directions to insure full protection.

Proper Maintenance of Signals.

59. While working under the protection of signals, great care shall be taken that the signals are intact and in their proper location and position. Disregard of signals shall be promptly reported to the .....
(Title)
.....

Signals for Double Track.

60. In using signals on double track, each track must be considered as a single track railroad upon which trains are likely to be run in either direction at any time.

RULES GOVERNING THE USE OF HAND, PUSH, MOTOR AND VELOCIPEDE CARS.

61. Care must be exercised by foremen and other employes in the use of hand, push, motor and velocipede cars. In order to avoid accident, they must protect themselves with the proper signals, when the view is obstructed. On moving hand cars at least one man must face the rear to look out for approaching trains.

62. Such cars must be protected from the weather and when not in use must be locked.

63. Cars must never be used or left on the main tracks or sidings unprotected. Loaded hand or push cars on the track are obstructions and must be protected by the proper signals.

64. They must not be attached to trains. When following trains, or other moving cars, they must not run closer than ten (10) rail lengths.

65. They must be kept in good order and inspected frequently for loose bolts or other defects.

66. Switches must not be thrown for such cars, unless loaded, and then only under the supervision of the foreman.

NEXT YEAR'S WORK.

For next year's work your Committee recommends that it be instructed to review the rules and instructions heretofore adopted by the Association and to recommend such changes and additions thereto as may seem desirable.

Respectfully submitted,

COMMITTEE ON RULES AND ORGANIZATION.

REPORT OF COMMITTEE X—ON SIGNALS AND INTERLOCKING.

A. H. Rudd, *Chairman;* L. R. Clausen, *Vice-Chairman;*
Azel Ames, A. S. Ingalls,
C. C. Anthony, J. C. Mock,
H. Baker, F. P. Patenall,
H. S. Balliet, J. A. Peabody,
W. B. Causey, W. B. Scott,
C. A. Christofferson, A. G. Shaver,
C. E. Denney, T. S. Stevens,
W. J. Eck, H. H. Temple,
W. H. Elliott, Edwin F. Wendt,
M. H. Hovey, J. C. Young,
G. E. Ellis, *Committee.*

To the Members of the American Railway Engineering Association:

On Subject No. 1, "Continue investigation of outline description of a comprehensive and uniform signal system, suitable for general adoption, conferring with proper committee of the American Railway Association," your Committee submits the following report:

As a result of several years' study, the Committee, in 1907, arrived at the conclusion that the basis of a uniform system of signals should be the control of the train. During the succeeding two years the Committee, after exhaustive study and investigation of the subject, was unable to agree,

First—As to the number of indications that should be given by fixed signals;

Second—As to the wording of the indications;

Third—As to the aspects or forms of the signals that should be used to represent the several indications.

In 1910, the American Railway Engineering Association requested the American Railway Association to bring the matter to the attention of its Committee on Transportation for decision. The Committee on Transportation heard arguments at a meeting in June of that year and reported as follows:

"MEMORANDUM OF THE ESSENTIALS OF SIGNALING,

"INCORPORATED IN THE REPORT OF THE COMMITTEE ON TRANSPORTATION OF THE AMERICAN RAILWAY ASSOCIATION, MAY, 1911.

"The reports of various Committees of the Railway Signal Association and of the American Railway Engineering Association on the subject of signaling have been submitted to this Committee, with the request that the essentials of signaling be outlined or defined for the future guidance of their Committees.

"The subject has been carefully analyzed and considered. There are

three signals that are essential in operation and therefore fundamental, viz.:

(1) Stop.
(2) Proceed with caution.
(3) Proceed.

"The fundamental, 'proceed with caution,' may be used with the same aspect to govern any cautionary movement; for example, when:

(a) Next signal is 'stop.'
(b) Next signal is 'proceed at low speed.'
(c) Next signal is 'proceed at medium speed.'
(d) A train is in the block.
(e) There may be an obstruction ahead.

"There are two additional indications which may be used where movements are to be made at a restricted speed, viz.:

(4) Proceed at low speed.
(5) Proceed at medium speed.

"Where automatic block system rules are in effect, a special mark of some distinctive character should be applied at the stop signal.

"The Committee therefore recommends:

"SIGNAL FUNDAMENTALS.

(1) Stop.
(2) Proceed with caution.
(3) Proceed.

Supplementary Indications to Be Used Where Required.

(4) Proceed at low speed.
(5) Proceed at medium speed.

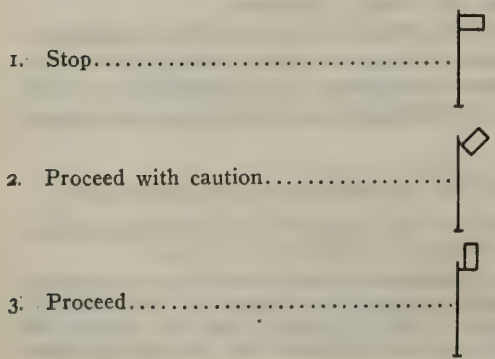
"Stop signals operated under automatic block system rules should be designated by some distinctive mark to be determined by each road in accordance with local requirements."

RECOMMENDATIONS OF COMMITTEE X.

Your Committee submits for approval the following two schemes of signaling in conformity with the recommendations of the Committee on Transportation.

Scheme No. 1.

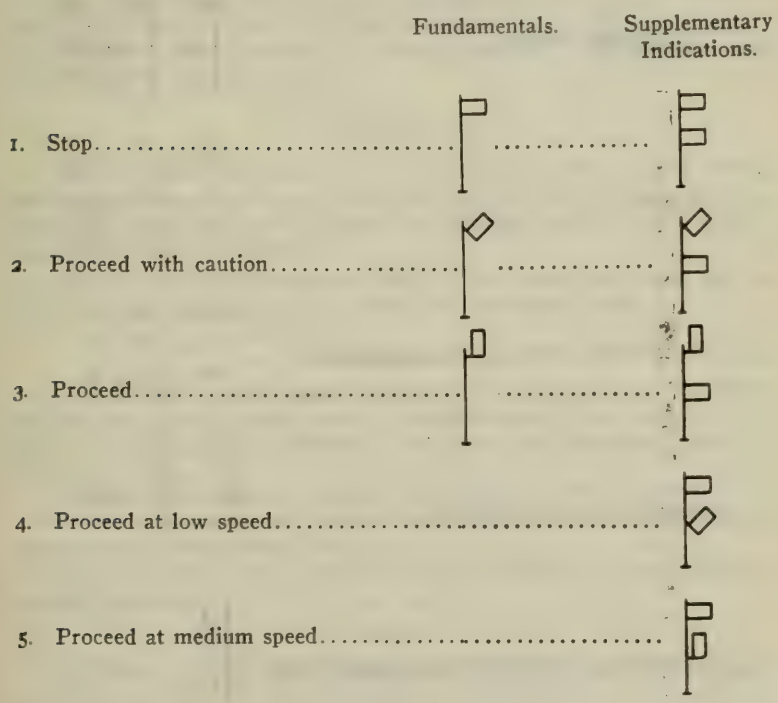
FUNDAMENTALS.



As means of designating stop signal operated under automatic block system rules, the following are suggested:

1. The use of a number plate; or
2. The use of a red marker light below and to the left of the active light; or
3. The use of a pointed blade, the blades of other signals giving the stop indication having square ends; or
4. A combination of these distinguishing features.

Scheme No. 2.

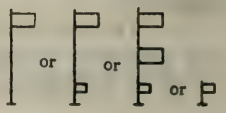


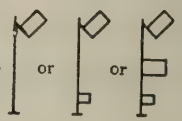
As means of designating stop signals operated under automatic block system rules, the following are suggested:

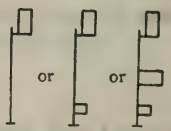
1. The use of a number plate; or
2. The use of a red marker light below and to the left of the active light; or
3. The use of a pointed blade, the blades of other signals giving the stop indication having square ends; or
4. A combination of these distinguishing features.

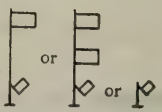
Having in view the practice of indicating diverging routes by several arms on the same mast, the Committee submits for approval the following to establish uniformity in this practice:

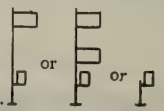
Scheme No. 3.

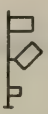
1. Stop..... 

2. Proceed with caution..... 

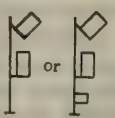
3. Proceed..... 

4. Proceed with caution on low-speed route..... 

5. Proceed on low-speed route..... 

6. Proceed with caution on medium-speed route... 

7. Proceed on medium-speed route.....

8. Reduce to medium speed..... 

As means of designating stop signals operated under automatic block system rules, the following are suggested:

1. The use of a number plate; or
2. The use of a red marker light below and to the left of the active light; or
3. The use of a pointed blade, the blades of other signals giving the stop indication having square ends; or
4. A combination of these distinguishing features.

The above three schemes are submitted, after an earnest effort to carry out the instructions to "outline description of a comprehensive and uniform signal system, suitable for general adoption," with the idea that each scheme is complete in itself.

CONCLUSION.

That the signal indications and aspects and the means of designating stop signals operated under automatic block system rules, presented above, be adopted, published in the Manual and referred to the American Railway Association as information.

On Subject No. 2, "Report on the effect of treated and metal ties on track circuits," your Committee submits the following report:

HISTORICAL.

In 1910 this Committee was instructed to confer with the Committee on Ties, and report on the effect of treated and metal ties on track circuits. Nothing was accomplished. (See page 128, Proceedings, Vol. 12, Part 1.)

In 1911 instructions were issued to report as above (omitting conference with Committee on Ties). Other subjects were given preference. (See page 70, Proceedings, Vol. 13.)

This is the third year, therefore, that the subject has been assigned to this Committee.

REPORT.

The effect of metal ties is self-evident. Each rail must be completely insulated from its ties to prevent a short circuit (similar to the action of the wheels and axle of a train).

Defective insulation at any point will cause leakage and defective insulation at both ends of only one tie will throw the track circuit out of service.

The effect of creosoted ties is not serious and, with alternating current track circuits, is negligible.

The effect of zinc treated ties is more problematical.

The response to the circular sent to all members on June 1 was most gratifying. One hundred and twenty-six replies were received, representing 92 railroads—many of them trunk lines. Sixty-nine of these use no zinc-treated ties; four use them to such a limited extent as to render a report valueless, including two which are making the first installation this year; seven use them extensively, but not where track cir-

cuits are in service; 12 only use them with track circuits, showing that, while the subject is decidedly important to these roads, it does not at the present time, in view of this small percentage, appear to be of great general interest; although, if it could be shown that this treatment did not affect circuits seriously, its use might be extended.

The following extracts from the reports of these 12 roads show that their experiences differ very considerably, due, doubtless, in some measure, to different methods of treatment, but mainly to varying conditions of track, roadbed and especially ballast:

(a) "We are obliged to cut or relay all of our track sections which exceed one-half mile in length, owing to the combined leakage due to treated ties, metal in our ballast and brine drippings. Therefore, none of our track circuits is more than one-half mile long, and with sections of this length we have no leakage trouble whatever, even on new lines where all of the ties are freshly treated.

"New zinc-treated ties undoubtedly increase the leakage at first, but the resistance seems to increase after they have been in service a year or so, and I do not think a 15 per cent. annual renewal would cause serious trouble on any track circuit of reasonable length if the conditions are fairly good otherwise.

(b) "Where track circuits were in operation and renewals were made of some 15 or 20 ties in one location, there was a considerably greater leakage of track circuit current than ordinarily. We had a number of intermittent working track sections. For some time we could not imagine what the trouble was; when finally we did discover it and improvements set in, in several cases the track circuits had to be shortened.

"It appears that in time the trouble diminished owing, as we believed, to the zinc treatment disappearing from the surface of the tie.

(c) "From our experience the influence of 15 per cent. new zinc-treated ties on a track circuit is not appreciable; in fact, we have observed no trouble in some instances where track circuits 4,000 feet long have been installed on new second track completely equipped with zinc-treated ties, and where ballast and drainage conditions were good.

"On the other hand, we have found it necessary in some instances to take out zinc-treated ties and replace them with untreated ties where track circuit conditions were unusually bad, and the slight effect of zinc-treated ties was sufficient to overcome the safe operating margin. Such conditions, however, are extremely rare, occurring for the most part through station platforms where the rails are buried in material sometimes having relatively high conductivity.

(d) "A strange coincidence, however, was the fact that in those track circuits in which the resistance seemed relatively low to the proportion of treated ties the ties were not uniformly spaced throughout the distance, but were bunched together at only a few points in each such track circuit. On the other hand, in other track circuits in which the resistance seemed relatively high in proportion to the number of treated ties the ties were spaced practically uniformly throughout the length of the track circuit. This would seem to indicate that the effect of a num-

ber of treated ties spaced closely is greater than their aggregate effect when spaced with several untreated ties between each two treated ones.

"In our investigation we also observed the electrolytic action first observed by Mr. V. I. Smart, of the Illinois Central, and reported in the Railroad Gazette of March 13, 1908. It was noted that the resistance between the two rails, while very low immediately after the installation of a number of treated ties, became appreciably greater after the ties had been in service a short time, due apparently to the insulation of spikes on the positive side of the circuit by the formation of chloride of iron crystals.

(e) "However, if they are permitted to dry thoroughly before being placed, we have not had any bad effects.

"We find, if these ties are put in track immediately after treating or while they are wet, we experience some trouble with leakage in our track circuits.

(f) "We afterward found that we could eliminate this trouble by letting the ties season, and I am quite sure if ties treated with chloride of zinc would be seasoned, you could put in more than 15 per cent. of them annually without interfering with the block signals.

"After the ties have been put in the track a sufficient length of time, even though they were not seasoned previously, the trouble will be eliminated.

"The experience on this road has been that where only a portion of the ties in a section are treated, it is necessary to use considerably more battery than where untreated ties are used, and I believe that if all the ties were zinc-treated, it would be very difficult to maintain a proper track circuit.

"The track circuit gets better as the ties get older and in three or four years gets back to almost the same condition as if ties were untreated. In some cases where zinc-treated ties were used on this road, it was found necessary to reduce the length of track sections to 2,000 feet, and with these short sections we still experienced considerable trouble in damp weather.

"My general experience has been that it is a very hard matter to maintain a proper track circuit in sections where these zinc-treated ties were in use.

(g) "The peculiarity of this treatment is that it causes the most trouble on dry days, and apparently has very little, if any, effect on track circuits in cold or wet weather.

(h) "Where zinc-treated ties are used in all the renewals, and where from eight (8) to fifteen (15) per cent. of the ties are renewed per year, no appreciable effect is produced on the track circuits.

"In cases where zinc-treated ties are laid continuously, I have found that the length of track circuits would have to be reduced about one-half.

(i) "While we were using the zinc-treated ties we had one case where we had an automatic signal circuit about one mile long. It became necessary to renew a portion of the ties on this part of the track, and in renewing the new ties placed in the track were zinc-treated. The

effect of the zinc was very noticeable, especially during wet periods. In fact the ties caused short circuits so that the signals would not work. The result was that we took out the zinc-treated ties and placed cypress ties. I do not know what per cent. of the total number of ties were renewed, but it would appear that it was possible to ruin a circuit with a very few ties.

(j) "The ordinary yearly renewals of ties cause no trouble. However, I have experienced cases where on new track all of the ties being treated caused us a good deal of trouble for a period of two or three months. After this time, the leakage stopped, or at least there was not enough of it to prevent the track circuits working.

"My judgment is that where one is putting in track circuits on zinc-treated ties for new track, that the track section should be made somewhat shorter than otherwise would be necessary.

(k) "We have been using ties treated with chloride of zinc for the last four or five years, and our men advise that they cannot trace any track circuit trouble to the fact that the ties are treated with chloride of zinc. I presume we renew, as a rule, about 15 to 16 per cent. of our ties annually.

(l) "With these treatments ('Burnettizing' and 'Card' systems) we find that no difficulty is experienced with track circuits of 3,500 feet (our standard length), provided that no more than 15 per cent. of treated ties is introduced in one season.

(m) "In reference to the attached, we have not many zinc-treated ties in our automatic territory, that is, not enough in any one spot to cause very much trouble. We had some trouble with some that were put in last year during the wet season, but it seems that this spring the trouble has disappeared, as we have had no failures on account of wet track so far.

(n) "In some of our zinc-treated ties, which were put in track before being properly seasoned, there was, for a short time, some interference with the circuit, but as soon as the salt on the outside of the tie washed off, the trouble ceased. At no time was this trouble serious.

(o) "We have track circuits where practically every tie is treated with this process and find no leakage at all.

(p) "In support of my contention that each tie is a battery, I wish to state that we obtained readings of .003 volt and eight mil-amperes on one of the track circuits, with the track battery and relay disconnected. In other words, the ties alone were producing this much electrical energy. The spikes also appear to have a somewhat shiny surface, such as we would expect from a battery electrode. We are able to pick out all treated ties by means of a voltmeter, by taking readings between one of the rails and a spike driven at random in the tie. On an untreated tie in the track circuit we merely get a slight deflection of the voltmeter needle.

(q) "A number of zinc chloride-treated ties were furnished for construction work and maintenance during 1911 and 1912.

"We now have treated ties in on 19 track circuits where treated ties

are causing trouble. Ten of these circuits are new and nine are old circuits in which treated ties have recently been placed in renewals.

"Our record of signal failures shows that the trouble commences when the treated ties are put in. The trouble on the treated tie track circuits is due to a weak track circuit; i. e., with a sufficiently powerful track battery at one end of the circuit, the relay at the other end is not energized, due to insufficient current. This condition could be caused by too high resistance of the track circuit or by the track circuit becoming short circuited. The behavior of track batteries shows it is the latter which takes place, the battery being exhausted in five or six days, due to increased current generated. If the trouble were due to increased track circuit resistance, the battery would have longer life.

"As no change has been made in our track circuits during the last year, other than to put in zinc chloride-treated ties, we feel sure the trouble is caused by the treated ties, as our records now show a large increase in the failures.

"At a distant signal a year ago the track battery was made up once in every 18 days. One signal failure was reported during 1911. This spring 360 zinc chloride-treated ties were put in on the 5,000-foot track circuit, and we now renew the track battery once every four days, and even this does not keep the signals working when it rains.

"At the circuit of another distant signal, 4,600 feet long, 140 treated ties are causing the same trouble.

"In addition the treated ties are spoiling our track relays. With a variable current at the relay near the amount which causes the relay to pick up, there is considerable sparking at the points, which open and close continuously. This causes the platinum points to burn furrows in the carbon contact points above them. The westbound distant signal stuck white with a train in the track circuit, August 12, due to platinum points on the relay being caught in the furrows they had burned in the carbon contacts above them.

"Each time it rains we have a number of failures, and the question should be studied to see what can be done to remedy the trouble. We tried, on one of the track circuits, oiling the ties inside the rail, thinking this might help, but it was not successful.

"Reports from other railroads show that the trouble disappears in time, but on this division the trouble is now on the increase."

SUMMARY.

The consensus of opinion is:

(1) That track circuits a mile in length are rendered inoperative by the extensive use of zinc-treated ties.

(2) That track circuits 2,000 feet in length may be operated successfully, even with 50 per cent. or more of ties so treated.

(3) That 10 per cent. to 15 per cent. renewals a year will not materially affect such length circuits.

(4) That, where renewals are made of 15 or 20 adjacent ties, the leakage is much greater than where they are made singly at uniform distances, i. e., with 15 per cent. renewals (every sixth or seventh tie).

(5) That, while the surface salts are present, more leakage occurs during wet weather than with untreated ties, as these wet salts form a better conductor than ordinary wet wood.

(6) That, in dry hot weather, the salts are drawn to the surface and constitute a more or less perfect conductor.

(7) That, after a period varying from three months to a year, these salts disappear and subsequently no interference is noticeable.

CONCLUSION.

That this report be received as information.

On Subject No. 3, "Economics in Labor of Signal Maintenance," your Committee begs to state that this subject is being considered with reference to the report in 1914.

Respectfully submitted,

COMMITTEE ON SIGNALS AND INTERLOCKING.

REPORT OF COMMITTEE XV—ON IRON AND STEEL STRUCTURES.

A. J. Himes, *Chairman;*
J. A. Bohland,
A. W. Buel,
Charles Chandler,
C. L. Crandall,
J. E. Crawford,
J. E. Greiner,
W. H. Moore,
Albert Reichmann,
O. E. Selby, *Vice-Chairman;*
C. C. Schneider,
G. E. Tebbetts,
L. F. Van Hagen,
F. O. Dufour,
C. E. Smith,
I. F. Stern,
F. E. Turneaure.
Committee.

To the Members of the American Railway Engineering Association:

The subjects assigned to this Committee for investigation during the past year were:

(1) Report on Rules for Instruction and Guidance of Inspectors in Mill, Shop and Field.

(2) Report on Methods of Protection of Iron and Steel Structures Against Corrosion.

(3) Study the Design of Built-up Columns, co-operating with other investigators and committees of other societies.

These subjects were assigned to sub-committees, only one of which has made a final report. A meeting of the whole Committee was held in Buffalo on September 9, 1912, at which ten members were present.

A final report on Rules for Instruction and Guidance of Inspectors in Mill, Shop and Field, accompanied by a general descriptive statement of qualities desired in an inspector, is given in Appendix A. The report, with the descriptive statement omitted, is recommended for adoption and publication in the Manual.

Mr. Buel presents a minority report in Appendix B.

Mr. Schneider desires that the report be referred back to the Commitee for further study.

A progress report on Design of Built-up Columns is given in Appendix C.

Mr. C. D. Purdon, Chief Engineer of the St. Louis Southwestern Railway, in a letter dated October 19, 1912, requests that the Committee take under consideration a specification for phosphor bronze castings for use in bridge structures. This subject has been presented to the Committee and is receiving careful attention.

Mr. W. S. Bouton, Engineer of Bridges of the Baltimore & Ohio Railroad, has called attention to the fact that "the recommendations adopted at the convention (March, 1912) with reference to third rail clearance diagrams conflicted with the clearance diagram for bridge structures, as shown in the Manual of 1911, page 404."

The matter was referred to Mr. George W. Kittredge, Chairman of the Committee on Electricity, who writes: "Referring to the attached correspondence, in regard to interference with the established bridge clearance diagram of the American Railway Engineering Association by the third rail clearance diagram, which was adopted by the Association at its March meeting, 1912, I have investigated this matter and would suggest that the attached diagram be referred to the Standing Committee on Iron and Steel Structures with the recommendation that as the established bridge clearance line indicated on the diagram between points 'A' and 'C' practically coincides with point 'B' on the third rail clearance diagram, that this line be modified so as to pass through point 'B' and that portion of the line between 'A' and 'B,' which is shown dotted on the diagram, be eliminated and in place thereof the clearance line for permanent way structures be substituted on roads where electric equipment is likely to be used."

This subject was referred to the Committee by the Secretary on October 24, 1912, and is still under consideration, no conclusion having yet been reached.

A letter from the Secretary dated September 18, 1912, informs the Committee that "the Railway Signal Association has intimated that it might be desirable to have a conference with the proper committee of this association on the question of joint action in the direction of adapting designs of drawbridges to the signal and interlocking appliances required." He then requests, at the suggestion of President Churchill, "will you kindly get in touch with Mr. C. C. Rosenberg, Secretary of the Railway Signal Association and arrange a conference." This matter has received attention and arrangements are in progress for such meeting.

CONCLUSIONS.

The recommendations of the Committee may be summarized as follows:

(1) That the report on Rules for Instruction and Guidance of Inspectors in Mill, Shop and Field be adopted and printed in the Manual.

(2) That the report of the Sub-Committee on the Design of Built-up Columns be received as a progress report.

Respectfully submitted,

COMMITTEE ON IRON AND STEEL STRUCTURES.

Appendix A.

REPORT OF COMMITTEE ON RULES FOR THE INSTRUCTION AND GUIDANCE OF INSPECTORS IN MILL, SHOP AND FIELD.

Primarily the purpose of inspection is to insure that the purchaser receives that for which he has bargained. The nature of inspection necessarily varies materially according to the thing inspected and the facilities therefor. It may be precise and definite, as in the use of an iron templet from which one seeks to secure exact agreement with a predetermined plan or it may be quite indefinite and depend largly upon the inspector's judgment, as in the case of inspecting lumber or sampling ore. In cases that are definitely matters of personal judgment, the inspector must decide and his decision should be final. It is presumed that his judgment is good and the contractor has agreed to accept it.

It is in the very nature of his occupation that an inspector shall have authority to approve and disapprove things which he is required to inspect. This authority must be exercised within reasonable limits, but as to what these limits are the inspector is obliged to be his own judge. Where he has doubt as to the propriety of his exercising such authority there are two courses for him to follow: He may report his action immediately for confirmation, or he may refer the matter to his superior for decision. Such reference may involve delay and be objected to by the contractor. The inspector, however, while endeavoring always to co-operate with the contractor and facilitate the execution of the work in every practicable manner, never should let his desire to please outweigh his better judgment. The inspector is the agent of his employer and as such is entitled to respect, but any respect which he may be shown will be more sincere and lasting if founded on his personal qualities. The character of an inspector reflects to a considerable extent the character of his employer. This fact frequently is overlooked. It is not far-fetched to assume that the shortcomings of any inspector indicate some weakness or deficiency in the make-up either of the man who employs him or the organization of which he forms a part.

The inspector without authority can be nothing more than a reporter. Where a large amount of labor is employed and rapid progress is being made, it is desirable that the inspector be clothed with authority and that his directions receive prompt attention. This condition can exist only where the inspector enjoys the full confidence of his superior and is supported in whatever action he may take. In case of error it is unquestionably best to correct it, even though such action might, at the time, appear to stultify the inspector. If, however, such things occur but seldom they will work no appreciable harm and the inspector should be above taking offence at any necessary reversal of his action. No excuse will justify the perpetuation of an error.

The rules that are made to govern the conduct of employes should be as perfect as the experience and wisdom of the employer permits, but discretion in their observance must be permitted in a degree corresponding to the capacity and responsibility of the employe. An inspector should fully understand the purpose of the rules made for his observance and place the attainment of that purpose above a blind observance of the rule.

The duty of the inspector is to guard the interests of his employer. These interests include:

Safety of trains, persons and property;
Quality of materials and workmanship;
Correctness of construction;
Economy.

Some of the means at his command for protecting these interests are:

(1) The careful observance of such instructions as may be received from time to time.

(2) Reports either received by him, as information concerning the status of the work at distant points, or prepared by him to exhibit the condition of the work under his immediate care.

(3) Familiarity with the various means of communication between or among the several parties interested in the work and promptness in attending to messages and correspondence.

(4) By recording daily, in a journal kept for that purpose, the facts concerning all events that may affect the relations between his employer and the contractor, his employer and the public, the contractor and the public. The term "public" is intended to include all third parties. The purpose of such a record is to aid in the settlement of disputes and claims that may arise because of or grow out of the work in hand.

The inspector should have some knowledge of bridge stresses and should be able to read drawings quickly and with accuracy. A knowledge of elementary mechanics and of the mechanics of materials will enable him to understand the reasons for many specifications and the ultimate effect of faults of various kinds. Some knowledge of those branches of bridge building with which he is not directly concerned will be of advantage to him in understanding the work of inspectors employed upon such work. For instance, the shop inspector should know something of mill inspection to aid in the discovery of any omission or defect in such inspection. A knowledge of detailed designing is often a help in meeting emergencies or overcoming unexpected difficulties. He should have such knowledge of the relations between the employer and his employes as will enable him to assist in maintaining harmony in the working force.

Temperamentally he should be judicial, diplomatic and not controversial. He should be deliberate in his consideration of new or unexpected conditions, but prompt and decisive in action. When making investigations and reports he should be thorough and exhaustive, in

order that the person using the reports may act thereon intelligently and correctly. He should be studious in order that he may always be well-informed concerning his work and on the alert to discover matters requiring special attention.

Some experience in business affairs will enable him to appreciate better than otherwise would be possible the relations between his employer and the contractor, and the necessity of maintaining harmony while at the same time securing the results desired.

An inspector's habits should be good, his honesty undoubted, and he should have a loyalty towards his employer that does not come from the payment of a salary.

It is too much to expect that any one inspector will have all of these qualifications. His value will, however, be measured by the degree and extent to which he does possess them. The salary which usually is paid an inspector is not sufficient to secure the services of a man who has acquired through development the qualities named, but we are sometimes fortunate enough to secure for inspectors men who are endowed by nature with such traits, and who have acquired experience through force of circumstances. A position which enables a man to hold the final word on constructions involving the expenditure of many thousands of dollars is one that can lack appreciation only when the employer is ignorant of its duties and the necessities from which they arise.

The inspector should be fully provided with the plans and specifications pertaining to the work. Often it is desirable that he should have masonry plans also in order that he may understand clearly the position which the structure is to occupy. He should have a copy of the contract or at least extracts therefrom covering those matters which might possibly need his attention. From time to time during the progress of the work he should be given special instructions covering its various phases. Should any further agreements or understandings be made or arrived at between the company which he represents and the contractor, he should be informed promptly concerning them. It does not inspire confidence in an inspector to leave him in the dark concerning matters which are within the scope of his work.

The character of the inspection will be determined to a large extent by the facilities offered. In a rolling mill it is not practicable for an inspector to witness all details of its operation. He must confine his efforts to the customary practice, seeking to learn all that he can of the subject, but not expecting or relying upon anything outside of the usual practice. Often it will happen that a wide-awake inspector will find much more work than it is possible for him to do. In such cases he should be given discretion in selecting the work to be given his first attention. He should then in the light of his own experience select those places where failures are most common and where, if failures do occur, the results are most serious.

Reports should be made at regular intervals defining the condition of the work and calling attention to matters of especial interest. Special

reports should be made upon the happening of some event of more than ordinary interest. The amount of detail or the fulness of the regular reports should be governed by instructions. In general an inspector's time is more valuable when employed upon the site of the work where things are actually being done than in the office tabulating results. If a large amount of clerical work is required it is better to employ a clerk than to permit the inspector to perform duties which would keep him out of sight of the work which he is to inspect.

INSTRUCTIONS FOR THE MILL INSPECTION OF STRUCTURAL STEEL.

(1) Study the contract and specifications and secure such information concerning the proposed structure as will permit a full understanding of the use to be made of the various items of the order.

(2) Secure copies of the mill orders, shipping directions and other information concerning the material to be inspected.

(3) Attend promptly when notified of the rolling of material and so conduct the inspection and tests as not to interfere unnecessarily with the operations of the mill.

(4) Have the test specimens prepared and properly stamped with the melt numbers by the manufacturer. Observe the selection and stamping of specimens and verify the melt numbers when practicable.

(5) Attend and supervise the making of tensile, bending and drifting tests. Make sure that the testing machines are properly handled and that the specified speed of pulling is not exceeded. Note the behavior of the metal and check and record the results of the tests.

(6) Select the bars or other members for full-size tests as specified. Supervise such tests and check and record their results.

(7) Secure from the manufacturer records of the chemical analyses of the melts and accept only those in which the specified contents of impurities are not exceeded.

(8) Secure pieces of the test ingots and test specimens and have check analyses made outside of the manufacturers' laboratory when the analyses furnished by the manufacturer are erratic or for any other reason appear to be incorrect.

(9) Examine each piece of finished material for surface defects before shipment, requiring the material to be handled in a manner that will permit the examination to be thorough and complete. This inspection should detect evidence of excessive gagging or other injury due to cold straightening.

(10) Report promptly the shipment of any material from the mill, whose surface inspection has been waived. Such material should be examined by the shop inspector.

(11) Verify the section of all material by measurement and by weight.

(12) Study the operations of the plant and become familiar with the various processes of manufacture.

Cultivate the acquaintance of the mill employes and become familiar with their work so as to have direct knowledge of the mill practice and determine as well as the circumstances permit the correctness of the mill practice in so far as it is covered by the specifications.

(13) Record all tests and analyses on the forms provided.

(14) Keep informed as to the progress of the work in the shop and endeavor to secure the shipment of material at such times and in such order as to avoid delay in the fabrication.

(15) Secure copies of the shipping lists and compare them with the orders and make regular statements of the material that has been rolled and shipped.

(16) Make reports weekly or as may be directed, submitting complete records of tests, analyses and shipments and such other information as may be required.

INSTRUCTIONS FOR THE INSPECTION OF THE FABRICATION OF STEEL BRIDGES.

(1) Acquire a full knowledge of the conditions of the contract, such as the time of delivery, the railway company's actual need of the work, the desired order of shipment, and any special features in connection with the delivery such as the position of the girders or truss members on cars at the bridge site.

(2) Study in advance the plans and specifications and see that all provisions thereof are complied with. These instructions are not to be construed as altering the specifications in any way.

(3) Endeavor to maintain pleasant relations with foremen and the workmen and by fairness, decisiveness and good sense interest them in the successful completion of the work.

(4) Attend constantly to the work, making inspection during the progress of the work in the shop, striving to keep up with the output in order that errors may be corrected before the work leaves the shop. Conduct the inspection so as not to interfere unnecessarily with the routine operations of the shop.

(5) When unusual circumstances require an explanation of the plans or some variation from the specified procedure, take the necessary action promptly.

(6) Study the field connections, paying particular attention to clearances and making notations on the drawings so that they may be checked rapidly.

(7) Check all bevels and field rivet holes.

(8) Give careful attention to the quality of the workmanship, the condition of the plain material, accuracy of punching, care in assembling, alignment of rivets, tightness of rivets, accuracy of finishing of machined joints, painting and general finish.

(9) Make sure that reamed holes are truly cylindrical and that drillings are not allowed to remain between assembled parts.

(10) Watch for bends, kinks, and twists in the finished members and make certain that when leaving the shop they are in proper condition for erection.

(11) Make sure that the webs of girders do not project beyond the flange angles and that the depth of web below the flange angles complies with the specification.

(12) Allow only the material rolled and accepted for the work to be used therein.

(13) Have the fabricated material shipped in the correct order for erection and in accordance with instructions, as far as practicable.

(14) Measure the width of each column and the lengths of all girders between columns when they are to be placed consecutively in a long row so as to insure that the columns and girders will not "build out" in erection so as to exceed the calculated length.

(15) Check "rights" and "lefts" and make sure that the proper number of each is shipped.

(16) Check base plates of girders before riveting and make sure that the camber is not reversed.

(17) Check the space provided for driving field rivets, allowing sufficient space for the pneumatic riveter.

(18) Examine field connections after riveting to insure proper fitting and ease of erection.

(19) Make sure that shop splices are properly fitted and that matched and milled surfaces to transmit bearing are in close contact during riveting as specified.

(20) Examine and measure bored pinholes carefully to insure proper dimensions and spacing and smoothness of finish.

(21) Measure the spacing center to center of the end connections for sections of I-beam floors or any similar construction in which the calculated spacing is liable to be exceeded because of the tendency of such work to "grow" as it is assembled.

(22) Make sure that stringers connecting to floor beams beneath the flange have sufficient clearance to care for their possible over-run in depth.

(23) Have the assembling of trusses and girder spans required by the specifications carefully done and, in any case, if a large number of duplicate parts are to be made, insure the accuracy of field connections by having an occasional part assembled with its connecting member. The number of parts to be so assembled should be governed by the workmanship. If errors are found, a sufficient number of parts should be assembled to make it reasonably certain that such errors have been eliminated.

Have through girder spans with I-beam floors partially assembled and at least one bracket bolted in its final position.

Have at least one upper and lower shoe of each kind assembled and make sure that there is no interference.

(24) Make sure that iron templets used for reaming are properly set and held to line.

(25) Secure match-marking diagrams for work which has been assembled and reamed and make sure that the match marks are plainly visible.

(26) Have proper camber blocking used in assembling trusses and secure the desired camber before the reaming is done.

(27) Require that all treads and supports for the drums of draw spans be carefully leveled with an instrument.

(28) Study carefully the machine details and discriminate between those dimensions which must be exact and those in which slight variations are permissible.

Determine in advance the desired accuracy of driving fits for bolts or keys and similar parts and make sure that such accuracy is attained.

(29) Examine castings carefully for blowholes and other imperfections and discriminate between such defects as are unimportant and those which render the castings unfit for use.

(30) Make sure that bushings, collars and similar parts are held securely in place.

(31) Make sure that all drum wheels, expansion rollers, turntable rollers and similar parts are exact in size, so as to carry equally the loads which may be placed upon them.

(32) Ascertain in advance that the paint provided complies with specifications. Watch carefully the painting directions and make sure that paint is properly applied and only where intended.

(33) Verify all shop marks and make sure that they are legible as well as correct.

(34) Have important members so loaded as to be headed in the right direction upon arrival at the site of the work.

(35) Try a few countersunk head bolts in the holes where they are to be used to insure a proper fit.

(36) Make sure that small pieces are bolted in place for shipment as shown on the plans and that other small parts are properly boxed or otherwise secured against loss.

(37) Make sure that rivets, tie rods, anchor bolts and miscellaneous parts are shipped so as to avoid delay in erection.

(38) Examine the field rivets to insure that they are free from fins or other defects.

(39) Exercise special care in the examination of all movable structures and particularly their moving parts.

(40) Make reports weekly or as directed, exhibiting carefully and concisely the actual conditions.

(41) Observe carefully and report such unusual difficulties as may be encountered and the means adopted in overcoming them and endeavor by a study of the details or other means to make recommendations which will prevent their recurrence in future work.

INSTRUCTIONS FOR THE INSPECTION OF BRIDGE ERECTION.

(1) Study and observe the plans and specifications for steel construction. Study the masonry plans and check the masonry as built with the steel plans.

(2) Familiarize yourself with the local conditions affecting erection. Make the acquaintance of the principal men engaged upon the work and of local residents whose interests may be affected thereby.

(3) Obtain and study carefully the employes' time table and be well posted concerning the time when regular and extra trains are due and their relative importance. Acquaint yourself with all special traffic arrangements made because of the work in hand.

(4) Secure full information concerning the conditions of the work in the bridge shop and the probable dates of shipment.

(5) Obtain reports of any uncompleted or erroneous work that must be attended to after arrival of the material in the field.

(6) Study the erection program in order to avoid delays and be able to recommend some other procedure in an emergency.

(7) Endeavor to have full preparations made before disturbing the track so that the erection may proceed rapidly and the period of such disturbance be made a minimum.

(8) Keep a record of the arrival of all materials. The contractor's record should be sufficient if available. Strive to anticipate any shortage of material and use all available facilities to hasten delivery of the needed parts.

(9) Study the progress of the work and determine whether it is likely to be completed in the time allotted. If not, endeavor to secure such additions to the force and equipment as will insure such completion.

(10) Make a daily record of the force employed and the distribution of labor, in a way that will assist in following clauses 9 and 23.

(11) Exercise a constant supervision of any temporary structure or falsework and make soundings if necessary with the purpose of discovering any evidence of failure or lack of safety and having it corrected before damage is done. Examine erection equipment with a view to its safety and adequacy.

(12) Be constantly on hand when work is in progress and note any damage to the metal, failure to conform to the specifications, or any especial difficulty in assembling.

(13) Make sure that each member of the structure is placed in its proper position. If match marks are used, examine them with care.

Endeavor to have the several members assembled in such order that no unsatisfactory makeshifts need be resorted to in getting some minor member in place.

(14) Prevent any abuse or rough usage of the material. Bending, straining and heavy pounding with sledges are included in such abuse.

(15) Watch carefully the use of fillers, washers and threaded members to see that they are neither omitted nor misused.

(16) Make certain that all parts of the structure are properly aligned and that the required camber exists before riveting. It is possible for a structure to be badly distorted although the rivet holes are well filled with bolts.

(17) Watch the heating of rivets to insure against overheating and to make sure that scale is removed.

Examine and test carefully all field-driven rivets and have any that are loose or imperfect replaced.

Have cut out and replaced all rivets, whether shop-driven or field-driven, that may be loosened during erection and riveting.

Prevent injury to metal while removing rivets.

(18) Present to the contractor at once for his attention any violation of the specifications or contract, and secure a correction or refer the matter to the proper authorities as soon as possible.

(19) Keep informed concerning the use of Company material and work trains and assist in procuring such material and trains when needed, and preserve a record thereof.

(20) Secure a match-marking diagram of any old structure to be removed and see that each part of such structure is properly marked in accordance therewith. Make a record of the manner of cutting the old structure apart and report any damage to the members of the old structure. Indicate by sketches or otherwise such repairs or replacements as will be found necessary in re-erection.

(21) Secure photographic records of progress and the important features of the work wherever practicable.

(22) Make a record of all flagging of trains, whether performed for the benefit of the contractor or otherwise, delays to trains, personal injuries, and accidents of every kind.

(23) Make reports as directed, showing the progress of the work, the size of the force and the equipment in use.

Make a final report showing the cost of labor of erection per ton of material erected, the cost of labor per rivet in riveting, the cost of correcting errors in design and fabrication and commenting on the design and details; and give such other information as may be useful in planning similar work.

Appendix B.

MINORITY REPORT.

To the Members of the American Railway Engineering Association:

At the Buffalo meeting of the Committee on September 9, the writer suggested that an effort be made to outline some method or system which would promise some improvement over existing mill and shop inspection, and that a co-operative railroad bureau, combining the good features of "company inspection" with those of "bureau inspection," deserves consideration, particularly on account of the very great advantages which the consolidation of a great tonnage would give, permitting the subdivision and specialization of work to a high degree under competent and experienced resident or district engineers and managers.

The chairman of the Committee, Mr. Himes, seemed to think that our instructions from the Board to "report on rules for instruction and guidance of inspectors in mill, shop and field," were not broad enough to include anything along the lines of this proposal and the matter was dropped. Now the writer would be glad to learn why our instructions cover an academic discourse on the personal attributes desirable in inspectors and their relation with and to the party of the first part, the party of the second part and "the public," but do not cover any consideration of the organization of which the inspector is an element and through which he must receive all instructions and rules that he gets. Though a perfect set of rules be devised and an inspector be found who has all the qualifications set forth in this report, if the organization which fixes the condition under which the work is done is not right, the results can not be satisfactory.

On every hand complaint is heard that bureau inspection is unsatisfactory. For over twenty-six years the writer has had an intimate acquaintance with bureau inspection, both from the inside and outside, and thinks that in several respects the conditions are less favorable for good work now than formerly. At one time a considerable number of inspectors were men with some engineering training, but it is now rather exceptional to find an inspector who has had any such education or experience. Many are men who have worked in bridge shops in the "laying out" and similar departments, where formerly men with some experience in the drafting and computing departments found inspection jobs attractive.

In former years, when the bureaus were much smaller concerns, the inspectors frequently came in contact with the principals, while now the time of the head men is so taken up with soliciting business, office routine and correspondence, that they rarely see inspectors, hardly ever to give detailed or technical instruction.

The founders of the best bureaus were competent and experienced bridge engineers, who took a professional interest in their inspection work, and had themselves been inspectors, while now, with two or three notable exceptions, one almost looks in vain for the name of a bridge engineer

in the bureau organizations. Owing to division of territory and exchange of work, sometimes a job taken by one bureau will be executed by an inferior one.

Within the past five years the writer had occasion to do personally a considerable amount of shop inspection, and was impressed with the change in conditions and shop practice that had occurred within a comparatively few years. Certainly he had all along an "appreciation" of these new conditions, but that is quite a different thing from the actual, detailed experience of working with them. This recent experience is the basis of the suggestion offered above.

Company inspection is sometimes better, but often worse, than bureau inspection, and even with all the work for a system of allied lines does not consolidate sufficient tonnage to permit such an organization with division of work and specialization as the writer has in mind.

As to mill inspection, all who know the conditions agree that it is largely a farce. A well-known bureau man, in confidential conversation, has admitted this to be so. The test reports are only of value for file, to bring out if anything ever happens, or as exhibits in court. While more difficult to improve than shop inspection, consolidation of a great tonnage, as suggested, would permit of a very material betterment in the quality of mill inspection at little more than current costs.

There is this to say on the other hand, particularly as to shop inspection, but also as to mill inspection: The shop and mill practice and standards have been so greatly improved since inspection by or for the purchaser became customary that there is nowhere near as great need for rigid inspection in each individual case. But unless the average inspection is kept up to a high standard and prevented from becoming a farce, there is danger of a lowering of the standard of quality for structural steel work and material. Not only that, but an incentive to further improvement will be lost.

The rules or instructions as drawn may be applicable to "company inspection," but it is not clear how they are going to be applied to bureau inspection, which represents the greater tonnage. They would be entirely inadequate for such a co-operative railway bureau as suggested above. It is the writer's opinion that they will only be useful for company inspection, and that even for this they should contain more detail of technical and practical kinds.

The ideas I have suggested with the purpose of improving shop and mill inspection may be expressed as follows:

First.—That the shop and mill inspection of structural steel, to be efficient and satisfactory, should be done on a scale large enough to economically permit the employment at each shop or mill of a corps of men, who may be called checkers, each one of whom is specially fitted and trained for a certain part or detail of the work under a resident inspecting engineer, thoroughly familiar with all details of structural steel and its fabrication, competent to direct the corps of checkers and decide questions calling for the judgment of a man of experience and structural

engineering training. Resident inspecting engineers should report to the District Chief Inspector or Manager, who should be an expert in structural steel and its fabrication, as well as a competent Bridge Engineer, and he in turn should report to the executive head of what may be called the American Railway Inspection Association; except that on technical matters and with proper regulations, he may report to and receive instructions from the Chief Engineers and Bridge Engineers of the railway companies which are members of the Association.

Second.—That the American Railway Engineering Association use its influence to induce the railway companies to delegate officials to meet and discuss ways and means and, if it appears practicable, to provide for establishing the American Railway Inspection Association as an organization to make a highly improved and standardized shop and mill inspection of structural steel, furnishing the same at cost to the railway companies which are members of or supporting such Association. As this can hardly become effective without the support of railway companies representing about 75 per cent. of the annual railway purchases of structural steel, it would seem desirable to have the official delegates empowered, under proper restrictions, to pledge the adherence of their respective companies to the support of the project.

The above outlines my ideas in as few words as the subject seems to permit. There are a number of details not mentioned at all which I should like to refer to in the following paragraphs.

Later on such an organization could be expanded to include the inspection of steel rails, but as this would require practically a separate corps—only the district chief and his office and probably a chemist, being common to the inspection of both structural and rail steel—it will no doubt be considered advisable to defer this question to a future time. However, as general officers and Chief Engineers are greatly interested in all matters respecting rails, it might aid in securing their co-operation to suggest the future possibility of the proposed American Railway Inspection Association taking up and standardizing rail inspection. The present status of rail inspection problems suggests that the time is hardly ripe to press this matter, but it would do no harm to refer to it as a future line.

The size of each shop corps should be about one man for each 10,000 tons' annual capacity of the shop; the number of independent inspectors at present employed is probably equal to or greater than that. This would require that the inspection of about 50 per cent. of the shop capacity be done by the proposed organization. Otherwise the cost of inspection would be greatly increased, and my object is to try to show that a very superior inspection method can be devised without *greatly* increasing the cost.

The District Chief, or Manager, ought to be a man worth at least $200 to $300 per month, depending on the importance of the district, and could cover a radius of, say, 100 miles from Pittsburgh, Chicago,

Philadelphia or Cleveland. Each resident inspecting engineer should be worth not less than $200 or $250 per month at the larger shops, down to a minimum of, say, $150 at the smaller shops. The wages of the other men in a shop corps would range from about $1.00 per day for the scale boy to $4.00 per day for the men checking field fits, templets and laying out. This will work out to between 40 cents and 50 cents per ton for shop inspection in average shops down to 30 cents per ton in the largest shops.

The following is a tentative outline of a shop inspection corps and an estimate of cost for a shop of 100,000 tons capacity per annum, in one unit. For shops of two units a somewhat different arrangement would be required, and in each case the organization of the corps will have to be adjusted to the plan and character of the particular shop concerned.

District chief or manager	$3,600.00	
District chief, office expense	3,600.00	
District chief, expense account	1,200.00	
	$8,400.00	
25 per cent. of $8,400.00		$ 2,100.00
Resident inspecting engineer	$3,000.00	
Templet checkers, 300 days @ $4.00	1,200.00	
Layout and punching checker, 300 days @ $4.00	1,200.00	
Assembling and fitting checker, 300 days @ $3.00	900.00	
Reaming and rivet checker, 300 days @ $2.00	600.00	
Machine and finished work checker, 300 days @ $3.00	900.00	
Field connection checker, 300 days @ $4.00	1,200.00	
Painting and yard work checker, 300 days @ $3.00	900.00	
Scale and weight boy, 300 days @ $1.00	300.00	
Clerk, 300 days @ $3.00	900.00	
		11,100.00
		$13,200.00
Add 15 per cent. for general expense		1,980.00
Total		$15,180.00

50 per cent. of 100,000 tons shop capacity—50,000 tons.

50,000 tons @ 30 36/100c $15,180.00

There would, of course, have to be a general office to which the District Chiefs or Managers would report, but on technical matters I think the District Chiefs or Managers should report directly to and receive instructions from the Chief Engineer or Bridge Engineer of the railway companies, subject to proper regulations where extra expense is involved.

While it is practically impossible to secure individual inspectors with all the qualifications recommended in the report of Committee XV, the desired combination of attributes may be closely approximated in such an organization as that outlined above.

Respectfully submitted,

A. W. Buel.

Appendix C.

STUDY OF BUILT-UP COLUMNS.

The following report of Sub-Committee No. 3, Study of Built-up Columns, showing status of the preliminary work of the Sub-Committee to date, is respectfully submitted: The Sub-Committee was named by the chairman on June 4, 1912, and the Chairman at once got into touch with the Chairman and Secretary of the American Society of Civil Engineers' Committee on Columns and Struts and ascertained the nature of the work being carried out under the direction of that Committee so that no duplication of such work would be made by your Sub-Committee.

The Chairman then took up with Mr. S. W. Stratton, Director of the Bureau of Standards, Washington, the question of the possibility of having several series of Column Tests made by the Bureau in its new 2,300,000-lb. Emery machine then being installed. Director Stratton kindly agreed to have such series made and agreed to begin the tests as soon as the machine was in commission. The Sub-Committee had its first meeting in Philadelphia on July 10th, and decided to make detail drawings for a preliminary series consisting of eight sections commonly found in the compression members and struts. A light and a heavy section of each type is to be made up in lengths giving three l/r ratios (50, 85 and 120) and three specimens of each column to be fabricated, making in all one hundred and forty-four (144) test columns.

The detail drawings were made up by Mr. J. E. Crawford, member of the Sub-Committee, and presented to the General Committee for discussion at its meeting in Buffalo on September 9, 1912. Ten members having expressed their satisfaction with this preliminary series, with some minor modifications, the chairman went to Washington on October 18th and arranged with Director Stratton and Mr. J. E. Howard to have the eighteen (18) columns representing Column No. 1, Series No. 1, at once fabricated and the tests commenced as soon as the final adjustments of the weighing apparatus were completed, and it is hoped that the tests will be under way before January 1, 1913. Before ordering the fabrication of the remaining columns of Series No. 1, the Committee will examine the results of the first eighteen (18) tests representing Column No. 1 and will probably then proceed with a sub-series on this column, changing one variable at a time in order to determine the best arrangement of details for the section. After the results of these tests are studied, the testing of the remaining columns of Series No. 1 will be proceeded with, making such modifications as may be suggested by the results of the tests of Column No. 1.

Respectfully submitted,

(Signed) W. H. Moore, *Chairman Sub-Committee No. 3.*

REPORT OF COMMITTEE V—ON TRACK.

J. B. JENKINS, *Chairman;*
GEO. H. BREMNER,
A. BRUNER,
GARRETT DAVIS,
RAFFE EMERSON,
E. G. ERICSON,
J. M. R. FAIRBAIRN,
T. H. HICKEY,
E. T. HOWSON,
J. R. LEIGHTY,
THOS. MANEY,
CURTISS MILLARD,
P. C. NEWBEGIN,
G. J. RAY, *Vice-Chairman;*
R. M. PEARCE,
H. T. PORTER,
W. G. RAYMOND,
S. S. ROBERTS,
L. S. ROSE,
H. R. SAFFORD,
C. H. STEIN,
F. S. STEVENS,
A. H. STONE,
W. J. TOWNE,
C. C. WENTWORTH,
Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Track respectfully submits its report to the fourteenth annual convention.

Meetings of the whole Committee were held at Chicago on May 17th and November 15th, in addition to the meetings of the several sub-committees.

Each of the three subjects assigned to your Committee was re-assigned to a sub-committee of eight members.

The work of the year was characterized by the keen interest manifested in all subjects under consideration, particularly in the subject of economics in track labor.

In addition to the work assigned, your Committee has supplemented and completed the Table of Functions of the Ten-Chord Spiral on pp. 102-110 of the Manual.

(1) PRESENT GENERAL SPECIFICATIONS FOR TRACK BOLTS, NUTLOCKS, TIE-PLATES, COMMON AND SCREW TRACK SPIKES.

G. J. Ray, Chairman; Geo. H. Bremner, Garrett Davis, Raffe Emerson, E. G. Ericson, T. H. Hickey, J. R. Leighty and W. G. Raymond, Sub-Committee.

Your Committee presents statements of general principles to be followed in the design and manufacture of tie-plates, track bolts and anti-creepers and specifications for steel tie-plates, malleable tie-plates, wrought-iron tie-plates, track bolts, spiral spring nutlocks, ordinary track spikes and screw spikes.

TIE-PLATES.

GENERAL PRINCIPLES TO BE FOLLOWED IN THE DESIGN.

The plates shall not be less than six (6) inches in width, and as much wider as consistent with the class of ties to be used.

The length of the plates shall be not less than the safe bearing area of the ties divided by the width of the plate, and, when made for screw spikes, shall be so shaped as to provide proper support for the screw spikes.

They shall be not less than five-eighths (⅝) of an inch thick along either edge of the base of the rail.

The thickness of the plate shall be properly proportioned to the length.

The plates shall have a shoulder at least one-half (½) of an inch high. The distance from the edge of rail base to the end of the tie-plate on the outer side must be uniform, and in excess of the projection inside of the rail base.

Where treated ties are used or where plates are for screw spikes, a flat bottom plate is preferable. Where ribs of any kind are used on base of plate, these shall be few in number and not to exceed one-quarter (¼) of an inch in depth.

The punching must correspond to the slotting in the splice bars and, where advisable, may be so arranged that the plates may be used for joints. Spike holes may be punched for varying widths of rail base where the slotting will permit such punching without the holes interfering with each other and when the plate is of such design that the additional holes will not impair the strength of the plate.

SPECIFICATIONS FOR STEEL TIE-PLATES.

Material.

The plates shall be made of Bessemer or open-hearth steel.

Physical Properties and Tests.

The tie-plates shall conform to the following requirements:

Ultimate strength,	not less than	55,000 lbs.	
Elastic limit,	"	"	"	50 per cent. of ultimate strength.
Elongation,	"	"	"	20 per cent. in 2 inches.
Reduction of area,	"	"	"	40 per cent.

Plates shall bend cold for 90 degrees without showing any sign of fracture.

A sufficient number of tests will be made to satisfy the inspector that the material meets the specifications in every respect.

Workmanship and Finish.

Subject to the following allowances, the form and dimensions of the plates shall conform to the drawings submitted to the manufacturer.

The length and width shall not vary more than one-eighth (⅛) of an inch from the dimensions shown.

The thickness shall not vary more than one thirty-second ($\frac{1}{32}$) of an inch from the dimensions shown.

All variations in length shall be left on the inside end of the plate.

The distance from the shoulder to the outside end of the plate must be made uniform.

The spike holes must be punched from the top, clean cut, without burrs, and the plates must not be cracked or bent out of shape in punching the holes.

All plates must be stamped on the top side, outside of the base of rail, with the section and weight of rail.

The plates shall be free from burrs and imperfections.

Inspection.

When required, the manufacturer shall furnish samples of tie-plates from a preliminary rolling before proceeding with the filling of the order and give sufficient notice in advance of the date when they will be ready for inspection.

The inspector representing the purchaser shall have free entry at all times, while the work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered.

The inspection shall be made at the mill and the manufacturer shall afford the inspector free of cost all reasonable facilities to satisfy himself that the plates are being furnished in accordance with these specifications. The tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Tests shall be made of samples of the finished product selected by the inspector from each lot of fifty bundles. Two pieces shall be selected for each test and if both meet the requirements of the specifications the lot will be accepted. If one of the test pieces fails a third test piece shall be selected and tested; if it meets the requirements of the specifications the lot will be accepted, but if it fails the lot will be rejected.

If, after shipment, any tie-plates are found to be defective due to material or manufacture, they may be rejected.

Shipping.

Tie-plates shall be wired together in bundles, the weight not to exceed 100 lbs., and shipped with a uniform number in each bundle.

SPECIFICATIONS FOR WROUGHT-IRON TIE-PLATES.

Material.

The plates shall be made of wrought-iron.

Physical Properties and Tests.

The ultimate strength shall be not less than 45,000 lbs.

Plates shall bend cold for 90 degrees without showing any sign of fracture.

A sufficient number of tests will be made to satisfy the inspector that the material meets the specifications in every respect.

Workmanship and Finish.

Subject to the following allowances, the form and dimensions of the plates shall conform to the drawings submitted to the manufacturer.

The length and width shall not vary more than one-eighth ($\frac{1}{8}$) of an inch from the dimensions shown.

The thickness shall not vary more than one thirty-second ($\frac{1}{32}$) of an inch from the dimensions shown.

All variations in length shall be left on the inside end of the plate.

The distance from the shoulder to the outside end of the plate must be made uniform.

The spike holes must be punched from the top, clean cut, without burrs, and the plates must not be cracked or bent out of shape in punching the holes.

All plates must be stamped on the top side, outside of the base of rail, with the section and weight of rail.

The plates shall be free from burrs and imperfections.

Inspection.

When required, the manufacturer shall furnish samples of tie-plates from a preliminary rolling before proceeding with the filling of the order and give sufficient notice in advance of the date when they will be ready for inspection.

The inspector representing the purchaser shall have free entry at all times, while the work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered.

The inspection shall be made at the mill and the manufacturer shall afford the inspector free of cost all reasonable facilities to satisfy himself that the plates are being furnished in accordance with these specifications.

These tests and inspections shall be so conducted as not to interfere unnecessarily with the operation of the works.

Tests shall be made of samples of the finished product selected by the inspector from each lot of fifty bundles. Two pieces shall be selected for each test and if both meet the requirements of the specifications the lot will be accepted. If one of the test pieces fails a third test piece shall be selected and tested; if it meets the requirements of the specifications the lot will be accepted but if it fails the lot will be rejected.

If after shipment, any tie-plates are found to be defective due to material or manufacture, they may be rejected.

Shipping.

Tie-plates shall be wired together in bundles, the weight not to exceed 100 lbs., and shipped with a uniform number in each bundle.

SPECIFICATIONS FOR MALLEABLE TIE-PLATES.

Material.

The plates shall be made from furnace malleable iron.

Physical Properties and Tests.

All plates must be cast with a lug for test purposes. The test lug when broken off must not break easily, as cast-iron, but must bend and show signs of toughness. The fracture must show a narrow band of white metal on the surface, center portion being dark and fibreless.

The plates must bend sufficiently to show thorough annealing.

A sufficient number of tests will be made to satisfy the inspector that the material meets the specifications in every respect.

Workmanship and Finish.

Subject to the following allowances, the form and dimensions of the plate shall conform to the drawings submitted to the manufacturer.

The length and width shall not vary more than one-sixteenth ($\frac{1}{16}$) of an inch from the dimensions shown.

The thickness shall not vary more than one thirty-second ($\frac{1}{32}$) of an inch from the dimensions shown.

All plates must be properly and thoroughly annealed.

All plates must be well cleaned and free from warping, shrinkage cracks, blow holes, fins, and other imperfections.

Inspection.

When required, the manufacturer shall furnish samples of tie-plates from a preliminary lot before proceeding with the filling of the order and give sufficient notice in advance of the date when they will be ready for inspection.

The inspector representing the purchaser shall have free entry at all times, while the work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered.

The inspection shall be made at the mill and the manufacturer shall afford the inspector free of cost all reasonable facilities to satisfy himself that the plates are being furnished in accordance with these specifications.

These tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

If after shipment, any tie-plates are found to be defective due to material or manufacture, they may be rejected.

Shipping.

Tie-plates shall be wired together in bundles, not to exceed 100 lbs., and shipped with a uniform number in each bundle.

TRACK BOLTS.

FACTS AND GENERAL PRINCIPLES TO BE TAKEN INTO CONSIDERATION IN THE DESIGN.

As a rule, as large track bolts should be used as the rail and splice bars will permit.

Bolts with rolled threads show a greater ultimate strength than those of the same size with cut threads. The elastic limit, however, is not materially different.

A workman pulling on a 33-inch wrench with a pull of 100 lbs. will load a ⅞-inch diameter bolt to the extent of 45,000 lbs. per square inch where the threads are in average condition. Therefore, it is easy to see how a bolt with a low elastic limit will readily be stretched in being tightened.

A ⅞-inch bolt with an elastic limit of 45,000 lbs. will require the same pull to stretch it as a 1-inch bolt with an elastic limit of 35,000 lbs. Again, a 1-inch bolt with an elastic limit of 75,000 lbs. requires over twice the pull to stretch it as a 1-inch bolt with an elastic limit of 35,000 lbs.

SPECIFICATIONS FOR TRACK BOLTS.

Material.

Steel shall be made by the open-hearth or other approved process. If necessary to secure the properties desired the bolts may be heat treated.

Physical Properties and Tests.

The bolts shall conform to the following requirements:

For carbon steel

Elastic limit	not less than	35,000 lbs. per sq. in.
Elongation,	" " "	25 per cent. in 2 inches.
Reduction of area,	" " "	50 per cent.

For untreated nickel or other alloy steel

Elastic limit,	" " "	45,000 lbs. per sq. in.
Elongation,	" " "	20 per cent. in 2 inches.
Reduction of area,	" " "	40 per cent.

For heat treated nickel or other alloy steel

Elastic limit,	" " "	75,000 lbs. per sq. in.
Elongation,	" " "	15 per cent. in 2 inches.
Reduction of area,	" " "	40 per cent.

Elastic limit shall in no case be less than 50 per cent. of the ultimate strength.

The elastic limit, elongation and reduction of area may be determined on a test piece ½ x 2 in. turned from a finished bolt.

The ductility of the bolts shall be determined by the cold bend test, which requires that the material used in the bolts shall bend cold through 180 degrees and flatten itself without fracture on the outside of the bent portion. This bend may be made on the unthreaded portion of a finished bolt, on a blank bolt, or on a test piece of the same size and same grade of steel, in any case, subjected to the same treatment as the finished bolt. It is not necessary that the bolt bend double in the threaded portion.

A sufficient number of tests shall be made to satisfy the inspector that the material meets the specifications in every respect.

Workmanship and Finish.

Subject to the following allowances, track bolts shall conform to the drawings submitted to the manufacturer:

The length shall not be more than one-sixteenth ($\frac{1}{16}$) of an inch less or one-eighth ($\frac{1}{8}$) of an inch more than the dimensions shown.

The diameter of the bolt shall not vary more than one sixty-fourth (1/64) of an inch from the dimensions shown.

The size of the head shall not vary more than one-sixteenth ($\frac{1}{16}$) of an inch from the dimensions shown.

The outside dimensions of the nut shall not vary more than one thirty-second ($\frac{1}{32}$) of an inch from the dimensions shown.

The shoulder of the bolt shall not vary more than one sixty-fourth (1/64) of an inch from the dimensions shown.

The heads and nuts shall be free from checks or burrs of any kind. They shall have the U. S. Standard upset thread unless otherwise specified. The threads may be either cut or rolled and shall be full and clean, with not less than two, nor more than five, finger threads.

Inspection.

When required, the manufacturer shall furnish samples of bolts from a preliminary rolling before proceeding with the filling of the order and give sufficient notice in advance of the date when they will be ready for inspection.

The inspector representing the purchaser shall have free entry at all times, while the work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered.

The inspection shall be made at the mill and the manufacturer shall afford the inspector free of cost all reasonable facilities to satisfy himself that the bolts are being furnished in accordance with these specifications. Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Tests shall be made of samples of the finished product selected by the inspector from each lot of 100 kegs. Two pieces shall be selected for each test and if both meet the requirements of the specifications the lot will be accepted. If one of the test pieces fails a third test piece shall be selected and tested; if it meets the requirements of the specifications the lot will be accepted, but if it fails the lot will be rejected.

If after shipment, any bolts are found to be defective due to material or manufacture, they may be rejected.

Marking and Shipping.

When the bolts are shipped they shall have the nuts applied for at least two threads, shall be properly oiled to prevent rusting and shall be packed in serviceable kegs. All kegs must be plainly marked as to material, size of bolts and name of manufacturer.

SPECIFICATIONS FOR SPIRAL SPRING NUTLOCKS.

Material.

The steel from which the nutlocks are made must be of open-hearth steel, or other approved process, and shall conform to the following chemical analysis:

Phosphorus, not over .05 per cent.
Sulphur, " " .05 per cent.

Physical Properties and Tests.

After the finished nutlock has been subjected to pressure sufficient to compress it flat for a period of one hour, its reaction shall not be less than two-thirds its height or thickness of section, providing thickness is less than width of section. If the section is square, the reaction must not be

less than one-half its thickness. If height or thickness of section is more than its width, reaction shall not be less than the width of the section.*

With one end of the finished nutlock secured in a vise, and the opposite end twisted to 45 degrees, there must be no sign of fracture. When further twisted until broken, the fracture must show a good quality of steel.

A sufficient number of tests will be made to satisfy the inspector that the material meets the specifications in every respect.

Workmanship and Finish.

The dimensions and form of the nutlock shall conform to the drawings submitted to the manufacturer.

The nutlocks shall be clean, without burrs or rough edges. The coil and cross-section shall be uniform throughout.

The manufacturer is required to guarantee:

First. That the steel was thoroughly annealed and permitted to assume its proper molecular structure before being made into nutlocks.

Second. That the subsequent heat treatment was scientifically accurate according to the best methods known, to secure uniformity of temper and the highest efficiency attainable.

Inspection.

When required, the manufacturer shall furnish samples of nutlocks from a preliminary lot before proceeding with the filling of the order, and give sufficient notice in advance of the date when they will be ready for inspection.

The inspector representing the purchaser shall have free entry at all times, while the work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered.

The inspection shall be made at the mill and the manufacturer shall afford the inspector free of cost all reasonable facilities to satisfy himself that the nutlocks are being furnished in accordance with these specifications. The tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Tests shall be made of samples of the finished product selected by the inspector from each separate heat treatment. Two pieces shall be selected for each test and if both meet the requirements of the specifications the lot will be accepted. If one of the test pieces fails a third test piece shall be selected and tested; if it meets the requirements of the specifications the lot will be accepted, but if it fails the lot will be rejected.

If after shipment, any nutlocks are found to be defective due to material or manufacture, they may be rejected.

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*NOTE. The internal diameters naturally affect the percentage of reaction, and the above specifications apply to nutlocks of internal diameters from 13/16 of an inch to 1 5/16 inches. Owing to the difficulty of establishing a common rate of percentage that shall be uniformly applicable to any internal diameter of any nutlock of any section, it has been sought to cover the matter as above. Amount and durability of reactionary power under constant pressure is the true test of any spiral spring nutlock. The percentage of reaction increases proportionately with the increased internal diameter of any given section.

Marking and Shipping.

When the nutlocks are shipped they shall be packed in good serviceable boxes. All boxes must be plainly marked as to material, size and number contained therein, and the name of the manufacturer.

SPECIFICATIONS FOR ORDINARY TRACK SPIKES.

Material.

Steel shall be made by the open-hearth or other approved process. If necessary to secure the properties desired the spikes may be heat treated.

Physical Properties and Tests.

The spikes shall conform to the following requirements:

Ultimate strength,	not less than	55,000 lbs.
Elastic limit,	" " "	50 per cent. of ultimate strength.
Elongation,	" " "	20 per cent. in 2 inches.
Reduction of area,	" " "	40 per cent.

The finished spike, when bent back on itself through 180 degrees and hammered down, shall show no signs of fracture.

When the head of the spike is bent backward cold it shall show no signs of fracture.

When the body of the spike is twisted cold one and one-half (1½) turns it shall show no signs of fracture.

A sufficient number of tests will be made to satisfy the inspector that the material meets the specifications in every respect.

Workmanship and Finish.

Subject to the following allowances, the form and dimensions of the spike shall conform to the drawings submitted to the manufacturer.

The thickness shall not vary more than one thirty-second ($\frac{1}{32}$) of an inch from the dimensions shown.

The length shall not be less, nor over one-quarter (¼) of an inch more, than the dimension shown.

The thickness of the head shall not vary more than one-sixteenth ($\frac{1}{16}$) of an inch from the dimensions shown.

The angle of the hook shall not vary more than one degree from that shown on the drawing.

The spikes must be neatly formed, free from burrs and rough edges, and have well-shaped heads and sharp points.

Inspection.

When required, the manufacturer shall furnish samples of spikes from a preliminary rolling before proceeding with the filling of the order and give sufficient notice in advance of the date when they will be ready for inspection.

The inspector representing the purchaser shall have free entry at all times, while the work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered.

The inspection shall be made at the mill and the manufacturer shall

afford the inspector free of cost all reasonable facilities to satisfy himself that the spikes are being furnished in accordance with these specifications. The tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Tests shall be made of samples of the finished product selected by the inspector from each lot of 100 kegs or bags. Two pieces shall be selected for each test and if both meet the requirements of the specifications the lot will be accepted. If one of the test pieces fails a third test piece shall be selected and tested; if it meets the requirements of the specifications the lot will be accepted but if it fails the lot will be rejected.

If after shipment, any spikes are found to be defective due to material or manufacture, they may be rejected.

Marking and Shipping.

When the spikes are shipped they shall be packed in good serviceable kegs or bags. All kegs or bags must be plainly marked as to material, size of spikes and name of manufacturer.

SPECIFICATIONS FOR SCREW SPIKES.

Material.

Screw spikes shall be made of open-hearth steel.

The chemical properties of the finished spike shall conform to the following limits:

Phosphorus, not over .05 per cent.
Sulphur, " " .05 per cent.

Physical Properties and Tests.

The finished spike shall conform to the following requirements:

Ultimate strength, not less than 60,000 lbs. per. sq. in.
Elastic limit, " " " 50 per cent. of ultimate strength.
Elongation, " " " 22 per cent. in 2 inches.
Reduction of area, " " " 40 per cent.

The material used in the spikes when bent cold through an angle of 180 degrees and hammered down shall show no signs of fracture.

The finished spike when bent cold through an angle of 90 degrees shall show no signs of fracture.

A sufficient number of tests will be made to satisfy the inspector that the material meets the specifications in every respect.

Workmanship and Finish.

The dimensions and form of the screw spike shall conform to the drawings submitted to the manufacturer.

All spikes shall be finished smooth and in a workmanlike manner, having no rough edges. They shall be of exact size, with symmetrical heads the axis of which must be situated in the direct line of the shank axis produced.

Inspection.

When required, the manufacturer shall furnish samples of spikes from a preliminary rolling before proceeding with the filling of the order

and give sufficient notice in advance of the date when they will be ready for inspection.

The inspector representing the purchaser shall have free entry at all times, while the work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered.

The inspection shall be made at the mill and the manufacturer shall afford the inspector free of cost all reasonable facilities to satisfy himself that the spikes are being furnished in accordance with these specifications. The tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Tests shall be made of samples of the finished product selected by the inspector from each lot of 100 kegs or bags. Two pieces shall be selected for each test and if both meet the requirements of the specifications the lot will be accepted. If one of the test pieces fails a third test piece shall be selected and tested; if it meets the requirements of the specifications the lot will be accepted, but if it fails the lot will be rejected.

If after shipment, any spikes are found to be defective due to material or manufacture, they may be rejected.

Marking and Shipping.

When the spikes are shipped they shall be properly oiled to prevent rusting and shall be packed in good serviceable kegs or bags. All kegs or bags must be plainly marked as to material, size of spike and name of manufacturer.

ANTI-CREEPERS.

GENERAL REQUIREMENTS TO BE MET IN THE DESIGN AND MANUFACTURE.

They shall be so designed as to fit two or more different weights of rail and show that they can be readily removed and re-applied.

They must be easy to apply under full-ballasted track.

They must be substantial enough to stand driving to place without chance of breaking.

The least possible number of movable parts is desirable.

When applied they must be in position rigidly enough to carry the tie with them in any kind of ballast without slipping.

They shall be made with sufficient take-up to permit of proper tightening.

They must not loosen when in place, or sufficiently to slip when the rail slacks back.

Controlling or delicate parts should be made of non-rustable material.

Anti-creepers made of steel shall be of sufficient size to minimize the destruction by rust.

Anti-creepers made of malleable iron must be from furnace malleable iron properly annealed, and of sufficient weight to prevent breakage and distortion in application or in service.

(2) CONTINUE STUDY OF DESIGN OF MAIN LINE TURNOUTS.

H. T. Porter, Chairman; A. Bruner, Thomas Maney, Curtiss Millard, R. M. Pearce, S. S. Roberts, A. H. Stone and C. C. Wentworth, Sub-Committee.

Your Committee presents typical plans illustrating recommended designs for Nos. 8, 11 and 16 main line turnouts.

In addition, your Committee has secured data as to the height of center of gravity of locomotives and tenders recently constructed and has under way a table showing the speed at which trains may be run through various turnouts and various curves with different elevations of outer rail, for publication as a matter of information. This information is not yet in shape for submission.

Your Committee has also begun the preparation of typical plans for cross-overs.

(3) ECONOMICS IN TRACK LABOR.

H. R. Safford, Chairman; J. M. R. Fairbairn, E. T. Howson, P. C. Newbegin, L. S. Rose, C. H. Stein, F. S. Stevens and W. J. Towne, Sub-Committee.

Your Committee adopted the following preliminary outline for future study, the plan being comprehensive and intended to cover the work of several years:

A system of reports to measure efficiency of gangs for various kinds of work and efficiency of various kinds of labor with a view to establishing tangible data to correctly measure efficiency.

A system of reports to establish unit costs of work.

The use of a system of work cards and other means of planning work and keeping records to measure progress.

The development of a plan and system for establishing a thoroughly accurate basis of comparison of track conditions as a means for measuring efficiency—equating for various conditions, such as rails, ballast, ties drainage, length of track, etc.

A study of the use and efficiency of motor cars for track work.

A study of labor-saving devices.

A study of the method best suited to various kinds of track work, particular reference being made to rail, ballast and tie renewals.

A study of the method of renewing ties, as to renewal of ties on every mile of track each year or taking a portion of the track each year to avoid disturbing track too often.

A study of the matter of proper season for various kinds of track work.

A study of the organization best suited to carry on the above work as to extra gangs versus section gangs.

A study of the general suggestion to combine under section foremen such work as ordinary maintenance of signals and telegraph lines, rough carpentry, water station repairs, etc.

Proper size of track supervisors' territory.

The establishment of a labor bureau to better control and secure labor.

Training laborers for track work by specially organized gangs for that purpose.

Rates of pay for section labor.

The matter of obtaining good section foremen.

The education of section foremen.

The rates of pay of section foremen.

The proper basis for providing section houses.

The subjects chosen for immediate investigation were:

(1) The matter of educating and securing section foremen.

(2) Method of making program of work and sequence of work.

Two circulars were prepared and submitted to the membership by the Secretary of the Association, dealing with these subjects.

A great deal of information has been received upon many features, some of which enables the Committee to reach a conclusion with reference to certain matters, and in other instances the information furnished is not in sufficient detail to enable a conclusion to be reached at this time, and these matters will be the subject of further research.

Your Committee wishes to express its appreciation of the response which met the requests for information. Practically all the replies were promptly and fully made and too voluminous to repeat in this report. The summary, however, contains a concise expression of the important points brought out in these letters; the replies to questions "A", "C" and "D", bearing upon the recommendation of your Committee and to questions "B" and "J", which are considered important as a matter of information, are transmitted herewith.

Eighty-seven replies were received to this circular, and the following represents the summary of the information received:

Questions "A" and "C":

"A" Has your Company in effect any plan for systematic education of men to fill places of section foremen?

"C" Do you have any defined plan of equipping gangs with apprentices and assistant foremen?

Of the total replies received

57 indicated no plan in effect.

23 reported the practice of employing assistant foremen.

6 reported the practice of employing apprentices.

1 reported the use of a "school gang" for the education of foremen.

1 reported no information.

2 reported the practice of using both assistant foremen and apprentices.

Question "D":

Do you have any defined plan of educating foremen as a class by instruction, such as educational bureaus, periodical meetings, etc.

Of the replies received

72 indicated no defined plan for education.

10 reported the practice of periodically instructing men through meetings.
3 reported the use of educational bureaus.
1 reported education by pamphlet, and
1 reported education by inspection trips to other roads.

Question "B":

From what classes of men do you now select foremen?

The intent of this question was to develop to what extent selections were made for foremen from certain nationalities or classes of labor, but the information received is quite general and not sufficiently specific to enable the sub-committee to give a very accurate opinion upon this matter, and this is to be made the subject of further research with a view to determining,

(1) The relative efficiency of various classes or nationalities.

(2) Information showing the number of each nationality employed.

(3) Their qualifications as to (a) honesty, (b) reliability, and (c) general efficiency.

(4) The effect, in employing foreigners for section foremen, in improving the supply of labor for ordinary section work with a view to overcoming the difficulties now existing in foreign labor desiring to work generally in large gangs.

Question "J":

What percentage of your foremen are foreign born?

25 report none employed.
27 report 25 per cent. or less.
16 report 50 per cent. or less.
8 report 75 per cent. or less.
7 report 100 per cent. or less, and
4 give no information.

After a complete consideration of these replies, your Committee is led to recommend the following as desirable agencies to obtain a better class of section foremen:

(a) The application of the principle of apprenticeship for a defined period during which the rate of pay shall be the same as a laborer, following which those men who show the necessary qualities for foremanship to be given an increase in compensation and the title of assistant foreman. From this position these men should be promoted to that of section foreman.

(b) The application of a method of education by periodical instruction in the form of meetings, at which supervising officers should instruct as to practice and encourage discussion between the men.

(c) The application where possible of an educational system, such as is being conducted on several of the larger railways, for which articles are written by supervising officers dealing with the best practices, which articles are printed and sent to foremen and assistant foremen free of cost, following which an examination is conducted and promotion depending upon results of such examinations.

LIST OF RAILROADS REPLYING TO QUESTIONS A, C, D, B AND J.

1. Atchison, Topeka & Santa Fe Railway.
2. Algoma Central & Hudson Bay Railway.
3. Baltimore & Ohio Railroad System.
4. Bangor & Aroostook Railroad.
5. Bellingham Bay & British Columbia Railroad.
6. Boston & Albany Railroad.
7. Boston & Maine Railroad.
8. Butte, Anaconda & Pacific Railway.
9. Canadian Pacific Railway.
10. Carolina, Clinchfield & Ohio Railway.
11. Central of Georgia.
12. Central Railroad of New Jersey.
13. Chicago, Burlington & Quincy Railroad.
14. Chicago Great Western Railroad.
15. Chicago Junction Railway.
16. Chicago, Indianapolis & Louisville Railway.
17. Chicago, Ottawa & Peoria Railway.
18. Chicago & Alton Railroad.
19. Chicago & Eastern Illinois Railroad.
20. Chicago & Northwestern Railway.
21. Chicago & Western Indiana Railroad.
22. Coal & Coke Railroad.
23. Cleveland, Cincinnati, Chicago & St. Louis Railway.
24. Colorado & Southern Railway.
25. Cumberland Valley.
26. Delaware & Hudson Company.
27. Delaware, Lackawanna & Western Railroad.
28. Denver & Rio Grande Railroad.
29. Detroit, Toledo & Ironton Railroad.
30. Duluth & Iron Range Railroad.
31. Elgin, Joliet & Eastern Railway.
32. El Paso & Southwestern System.
33. Ft. Dodge, Des Moines & Southern Railroad.
34. Georgia Railroad.
35. Georgia Southern & Florida Railway.
36. Grand Trunk Railway System.
37. Green Bay & Western, also Keewaunee, Green Bay & Western.
38. Gulf & Ship Island Railroad.
39. Illinois Traction Company.
40. Indiana Harbor Belt.
41. Intercolonial of Canada.
42. Lake Superior & Ishpeming Railway.
43. Lehigh & New England Railroad.
44. Lake Erie & Western Railroad.
45. Lake Shore & Michigan Southern Railway.
46. Lehigh Valley Railroad.

47. Morgan's Louisiana & Texas Lines.
48. Long Island Railroad.
49. Louisiana & Arkansas Railway.
50. Louisiana & Northwest Railroad.
51. Louisville & Nashville Railroad.
52. Maine Central Railroad.
53. Michigan Central Railroad.
54. Minneapolis & St. Louis Railway.
55. Missouri Pacific Railway.
56. Monongahela Railroad.
57. Nashville, Chattanooga & St. Louis Railway.
58. New Orleans Great Northern Railroad.
59. New York, New Haven & Hartford Railroad.
60. Norfolk & Western Railway.
61. Oregon, Washington Railroad & Navigation Company.
62. Pennsylvania Railroad.
63. Pennsylvania Lines West of Pittsburgh.
64. Philadelphia & Reading Railway.
65. Pittsburgh, Shawmut & Northern Railroad.
66. Pittsburgh & Lake Erie Railroad.
67. Queen & Crescent Route.
68. Richmond, Fredericksburg & Potomac Railroad.
69. Rutland Railroad.
70. San Pedro, Los Angeles & Salt Lake Railroad.
71. Seaboard Air Line.
72. St. Louis & San Francisco Railroad.
73. St. Louis Southwestern Railway.
74. Southern Pacific.
75. Southern Pacific of Mexico.
76. Spokane, Portland & Seattle Railway.
77. Sydney & Louisburg Railway.
78. Terminal Railroad Association of St. Louis.
79. Texas & Gulf Railway.
80. Texas Midland Railroad.
81. Tonopah & Goldfield Railroad.
82. Toronto, Hamilton & Buffalo Railway.
83. Toledo & Ohio Central—Zanesville & Western.
84. Vandalia Railroad.
85. Wheeling & Lake Erie Railroad.
86. Wabash Railroad.
87. Washington Terminal Company.

Replies to Questions "A", "C" and "D":

A. Has your company in effect any plan for systematic education of men to fill places of section foremen?

C. Do you have any defined plan of equipping gangs with apprentices and assistant foremen?

D. Do you have any defined plan of educating foremen as a class by instruction, such as educational bureaus, periodical meetings, etc.?

Road.	"A"	"C"	"D"
1.	No	No	No
2.	No	No	No
3.	Position of leading laborer created and special attention to educate them.	Same as "A"	No
4.	None other than circular letters, photographs and blue prints.	No	No
5.	No	No	No
6.	No	Asst. Foremen.	By annual meetings of foremen.
7.	No	Endeavor to obtain technically educated men.	No
8.	No	No	No
9.	No	Asst. Foremen.	No
10.	Yes	Apprentices at higher rate than laborers.	No
11.	Use of apprentice foremen at higher rate than laborers.	Same as "A".	Have educational bureau.
12.	Use Asst. Foremen.	English speaking Asst. Foremen.	Periodical instruction on book of rules and track work.
13.	No	No	No
14.	No	No	Nothing other than distribute pamphlets.
15.	No	No	No
16.	No	No	No
17.	No	No	By monthly meetings.
18.	No	No	No
19.	Yes, by paying one man higher wages than laborer and educate him as subforeman.	No	No

Road.	"A"	"C"	"D"
20.	No	Yes, appoint student foremen.	No
21.	No	No	No
22.	By calling upon certain laborers to fill section foremen's places temporarily and judging their fitness for promotion.	No	No
23.	No	Pay one man on each section little higher rate than laborers and educate him as Asst. Foreman.	No
24.	No	No	No
25.	No	No	No
26.	No	No	No
27.	No	No	Meetings are held spasmodically and sometimes foremen instructed in construction of frogs and switches in shops.
28.	No	No	No
29.	No	No	No
30.	No	No	Meeting in spring and trip over entire line in fall.
31.	No	None, considering advisability of appointing one man in each gang to act as foreman in man's absence.	Occasional meetings.
32.	No	No	No
33.	Yes, by securing young men and educating them up for positions as section foremen.	No	Monthly meetings.
34.	No	Put apprentices in yard gangs, and assign 4 apprentices to each 100 miles of road.	No

Road.	"A"	"C"	"D"
35.	No	No	No
36.	No	No	No
37.	No	No	No
38.	No	Assign 2 apprentices to each supervisor at higher wage than laborer and educate them to take position as section foreman.	No
39.	No	No	No
40.	No	No	No
41.	No	Employ good men and promote to act as extra men and secure permanent foremen from among them.	No
42.	No	No	No
43.	No	No	No
44.	No	Educate Asst. Foremen.	Periodical meetings twice a year.
45.	No	Asst. Foremen.	No
46.	No	Have Asst. Foremen only.	No.
47.	Have organized school with one foreman and 20 Japanese laborers, and educate them for positions as section foremen.	No	Have educational bureau, which conducts an instruction course by means of pamphlets, books and other literature.
48.	No	Have one sub-foreman in each gang selected from best and most intelligent men.	No
49.	No	No	No
50.	No	No	No
51.	No	No	No
52.	No	No	No
53.	No	No	No
54.	No	No	No
55.	No	No	No
56.	No	No	By monthly meetings.
57.	No	No	No

Road.	"A"	"C"	"D"
58.	Yes, have apprentice system.	Large gangs have Asst. Foremen or apprentices.	No
59.	No	No	No
60.	No	Use best men as relieving foremen and promote them to section foremen.	No
61.	No	No	No
62.	No	No apprentices, but Asst. Foremen on all main lines and important divisions.	No
63.	No	No	No
64.	No	From Asst. Foremen.	No
65.	No	No	No
66.	Yes	Yes	No
67.	No	Yes, have both apprentices and Asst. Foremen.	Meetings held three times a year, and educational talks given by roadmaster and supervisor.
68.	Yes. Have one or two young men in each gang and educate them as foremen.	See "A."	No
69.	No	No	No
70.	No	No	No
71.	No	Allow 3 apprentices to each roadmaster's district and Asst. Foremen in extra gangs.	No
72.	No	No	No
73.	No	No	No
74.	Yes. Each Roadmaster's district is allowed 5 extra men, rated as Asst. Foremen, who are paid higher wages than ordinary laborers and educated for position as foreman.	No	No

Road.	"A"	"C"	"D"
75.	None, except to pay promising young men 25 to 50 cents per day more than ordinary laborers to induce them to stay in the service.	No	No
76.	No	No	No
77.	No	No	No
78.	Yes	Yes, have apprentices.	No
79.	Educate one laborer in each gang for foreman.	No	No
80.	No	No	No
81.	No	No	No
82.	No	No	Not yet, but expect to inaugurate monthly meetings.
83.	No	Use Asst. Foremen in large extra gangs and promote them to regular section foremen.	No
84.	No	No	No
85.	No	No	No
86.	No	No	No
87.	From best white track laborers.	Likely-looking men are watched carefully to determine their fitness for promotion to foremen.	Take foremen for trip to large terminals on other roads occasionally for observation and education.

Replies to Questions "B" and "J":

B. From what classes of men do you now select foremen?

J. What percentage of your foremen are foreign born?

Road.	"B"	"J"
1.	Best selections from applicants from other roads	Nil
2.	Promotion from gang	50 per cent.
3.	From loading laborers and Asst. Gang Foremen	9 per cent.
4.	From English-speaking men	Nil
5.	From own ranks and other companies	85 per cent.
6.	Own ranks	Very small
7.	Own ranks	5 per cent.
8.	Own ranks	Large percentage
9.	Own ranks	No information

Road.	"B"	"J"
10.	White native labor	Nil
11.	White laborers previously trained as apprentices or foremen on other roads	Very few
12.	English-speaking Asst. Foremen	4 per cent.
13.	From better class of laborers	———
14.	From section laborers	10 per cent.
15.	From experienced men on other lines	33 per cent.
16.	Mostly Americans	Nil
17.	From practical experience in track work	33 per cent.
18.	Americans of experience and proper qualifications	10 per cent.
19.	Select from laborers	Nil
20.	From section foremen, station foreman and extra gang foremen	40 per cent.
21.	Employ foremen as opportunity offers	60 per cent.
22.	Native-born trackmen	Nil
23.	From laborers with experience and ability	30 per cent.
24.	From experienced laborers	Large number
25.	From Asst. Foremen who are promoted from the ranks	Nil
26.	Own ranks, native laborers preferred	40 per cent.
27.	Own ranks	55 per cent.
28.	From most promising laborers	50 per cent.
29.	Native laborers	Nil
30.	From most competent track laborers	95 per cent.
31.	Own ranks and from other roads	42 per cent.
32.	Own ranks	———
33.	White track laborers	10 per cent.
34.	From competent apprentices	Nil
35.	Farmers	Nil
36.	Track laborers	1 per cent
37.	No preference, but take mostly Norwegians and Germans	50 per cent.
38.	Farmers and railroad men desiring to become section men	Nil
39.	From own ranks and other roads	8 per cent.
40.	From foreign laborers	75 per cent.
41.	Own ranks	Nil
42.	From laborers who can read and write English	34 per cent.
43.	Own ranks and other roads	20 per cent.
44.	Native Americans	20 per cent.
45.	From best available men	31 per cent.
46.	Track laborers	10 per cent.
47.	Track laborers	95 per cent.
48.	From sub-foremen	85 per cent.
49.	From track laborers and other roads	10 per cent.
50.	From other roads	Nil
51.	From apprentice foremen	Very small
52.	From track laborers	50 per cent.
53.	Own ranks	Very few

Road.	"B"	"J"
54.	From own ranks and other roads	Nil
55.	Native white, negroes and Italians	8 per cent.
56.	From competent track laborers	50 per cent.
57.	From track laborers	Nil
58.	Laborers	Nil
59.	Assistant foremen, track walkers and competent laborers	60 per cent.
60.	From track laborers long in service	Nil
61.	From track laborers	Nil
62.	Native track men	25 per cent.
63.	Track laborers	10 per cent.
64.	Track	20 per cent.
65.	From Italian and Austrian laborers	60 per cent.
66.	From native Americans	Nil
67.	Track laborers	Very few
68.	Have one or two young men in each gang and educate them as foremen	Nil
69.	From native track laborers where possible and later Italians	10 per cent.
70.	Track laborers	64 per cent.
71.	Native laborers	Nil
72.	From track laborers and men on other roads	5 per cent.
73.	From track laborers and men from other lines	25 per cent.
74.	From native laborers and men from other roads	35 per cent.
75.	From track laborers and men from other roads	20 per cent.
76.	From track laborers	70 per cent.
77.	Laborers in neighborhood	Nil
78.	Try to get Americans	Nil
79.	From track laborers	Mostly negroes
80.	Experienced men from other lines	100 per cent.
81.	Experienced men from other lines	30 per cent.
82.	From native or British born men	Nil
83.	Section laborers	5 per cent.
84.	From track laborers	Very few
85.	From track laborers	50 per cent.
86.	From intelligent track laborers, and from foremen on other lines	66 per cent.
87.	From white men able to read and write	100 per cent.

SPIRALS.

By J. B. Jenkins.

The Table of Functions of the Ten-chord Spiral adopted by the Association in 1911 gave the values of the spiral tangents (U and V) for every degree only and did not include any values for the co-ordinates of the offsetted T. C. (o and Z) as these values depend on degree of curve as well as on central angle. A practical method of tabulating these functions has been found, and their values computed, as well as those of the spiral tangents, for every tenth of a degree. The results of the computation are submitted herewith to complete the table in the Manual.

Referring to the Manual, p. 99:

$$R = \frac{50}{\sin \frac{1}{2} D} \qquad (10)$$

expands to $$R = \frac{5729.58}{D} + .073D \text{ (Approx.)} \qquad (10a)$$

The error not exceeding 0.0023 ft. for any degree of curve up to 24 degrees.

Substituting the value of R given by (10a) in the formula

$$Z = X - R \sin \Delta \qquad (11)$$

we have $$Z = X - \frac{5729.58 \sin \Delta}{D} - .073 D \sin \Delta$$

Substituting the value of D given by

$$\Delta = \frac{DL}{200} \qquad (2)$$

we have $$Z = X - \frac{28.6479 L \sin \Delta}{\Delta} - .073 D \sin \Delta \qquad (11a)$$

Similarly,

$$o = Y - \frac{28.6479 L \text{ vors } \Delta}{\Delta} - .073 D \text{ vors } \Delta \qquad (12a)$$

These equations being in the general form

$$Z = m L - n D$$

and

$$o = m L - n D$$

in which m and n are variables depending on Δ, an accurate means is thus provided for calculating Z and o for tabulation.

The table published in the Manual has been entirely recalculated and several corrections made of one in the sixth decimal place where the seventh figure was a 5 and the eighth figure had not been determined by the first calculation.

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

U/L	V/L	o = mL − nD		Z = mL − nD		Δ
		m	n	m	n	
.666 667	.333 333	.000 000	.000 00	.500 000	.000 00	0.0°
.666 667	.333 333	.000 145	.000 00	.500 000	.000 13	0.1°
.666 667	.333 334	.000 291	.000 00	.500 000	.000 25	0.2°
.666 668	.333 334	.000 436	.000 00	.500 000	.000 38	0.3°
.666 668	.333 335	.000 582	.000 00	.499 999	.000 51	0.4°
.666 669	.333 336	.000 727	.000 00	.499 999	.000 64	0.5°
.666 671	.333 337	.000 873	.000 00	.499 998	.000 76	0.6°
.666 672	.333 338	.001 018	.000 01	.499 998	.000 89	0.7°
.666 674	.333 340	.001 164	.000 01	.499 997	.001 02	0.8°
.666 675	.333 341	.001 309	.000 01	.499 996	.001 15	0.9°
.666 677	.333 343	.001 454	.000 01	.499 995	.001 27	1.0°
.666 680	.333 345	.001 600	.000 01	.499 994	.001 40	1.1°
.666 682	.333 347	.001 745	.000 02	.499 993	.001 53	1.2°
.666 685	.333 350	.001 891	.000 02	.499 992	.001 66	1.3°
.666 688	.333 352	.002 036	.000 02	.499 990	.001 78	1.4°
.666 691	.333 355	.002 182	.000 03	.499 989	.001 91	1.5°
.666 694	.333 358	.002 327	.000 03	.499 987	.002 04	1.6°
.666 698	.333 362	.002 472	.000 03	.499 986	.002 17	1.7°
.666 701	.333 365	.002 618	.000 04	.499 984	.002 29	1.8°
.666 705	.333 369	.002 763	.000 04	.499 982	.002 42	1.9°
.666 710	.333 372	.002 909	.000 04	.499 980	.002 55	2.0°
.666 714	.333 376	.003 054	.000 05	.499 978	.002 68	2.1°
.666 719	.333 381	.003 200	.000 05	.499 976	.002 80	2.2°
.666 723	.333 385	.003 345	.000 06	.499 974	.002 93	2.3°
.666 728	.333 390	.003 490	.000 06	.499 972	.003 06	2.4°
.666 734	.333 394	.003 636	.000 07	.499 969	.003 18	2.5°
.666 739	.333 399	.003 781	.000 08	.499 967	.003 31	2.6°
.666 745	.333 405	.003 927	.000 08	.499 964	.003 44	2.7°
.666 751	.333 410	.004 072	.000 09	.499 962	.003 57	2.8°
.666 757	.333 415	.004 218	.000 09	.499 959	.003 69	2.9°
.666 763	.333 421	.004 363	.000 10	.499 956	.003 82	3.0°
.666 770	.333 427	.004 508	.000 11	.499 953	.003 95	3.1°
.666 776	.333 433	.004 654	.000 11	.499 950	.004 07	3.2°
.666 783	.333 440	.004 799	.000 12	.499 947	.004 20	3.3°
.666 791	.333 446	.004 945	.000 13	.499 943	.004 33	3.4°
.666 798	.333 453	.005 090	.000 14	.499 940	.004 46	3.5°
.666 806	.333 460	.005 235	.000 14	.499 936	.004 58	3.6°
.666 813	.333 467	.005 381	.000 15	.499 933	.004 71	3.7°
.666 822	.333 474	.005 526	.000 16	.499 929	.004 84	3.8°
.666 830	.333 482	.005 671	.000 17	.499 925	.004 97	3.9°
.666 838	.333 490	.005 817	.000 18	.499 922	.005 09	4.0°
.666 847	.333 498	.005 962	.000 19	.499 918	.005 22	4.1°
.666 856	.333 506	.006 108	.000 20	.499 914	.005 35	4.2°
.666 865	.333 514	.006 253	.000 21	.499 909	.005 47	4.3°
.666 874	.333 522	.006 398	.000 22	.499 905	.005 60	4.4°
.666 884	.333 531	.006 544	.000 23	.499 901	.005 73	4.5°
.666 894	.333 540	.006 689	.000 24	.499 896	.005 85	4.6°
.666 904	.333 549	.006 834	.000 25	.499 892	.005 98	4.7°
.666 914	.333 558	.006 980	.000 26	.499 887	.006 11	4.8°
.666 924	.333 568	.007 125	.000 27	.499 882	.006 24	4.9°
.666 935	.333 578	.007 270	.000 28	.499 877	.006 36	5.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.666 935	.333 578	.007 270	.000 28	.499 877	.006 36	5.0°
.666 946	.333 587	.007 416	.000 29	.499 872	.006 49	5.1°
.666 957	.333 598	.007 561	.000 30	.499 867	.006 62	5.2°
.666 968	.333 608	.007 706	.000 31	.499 862	.006 74	5.3°
.666 979	.333 618	.007 852	.000 32	.499 857	.006 87	5.4°
.666 991	.333 629	.007 997	.000 34	.499 852	.007 00	5.5°
.667 003	.333 640	.008 142	.000 35	.499 846	.007 12	5.6°
.667 015	.333 651	.008 288	.000 36	.499 841	.007 25	5.7°
.667 028	.333 662	.008 433	.000 37	.499 835	.007 38	5.8°
.667 040	.333 674	.008 578	.000 39	.499 829	.007 50	5.9°
.667 053	.333 685	.008 724	.000 40	.499 824	.007 63	6.0°
.667 066	.333 697	.008 869	.000 41	.499 818	.007 76	6.1°
.667 079	.333 709	.009 014	.000 43	.499 812	.007 88	6.2°
.667 093	.333 721	.009 159	.000 44	.499 805	.008 01	6.3°
.667 106	.333 734	.009 305	.000 45	.499 799	.008 14	6.4°
.667 120	.333 746	.009 450	.000 47	.499 793	.008 26	6.5°
.667 134	.333 759	.009 595	.000 48	.499 786	.008 39	6.6°
.667 148	.333 772	.009 740	.000 50	.499 780	.008 52	6.7°
.667 163	.333 785	.009 886	.000 51	.499 773	.008 64	6.8°
.667 178	.333 799	.010 031	.000 53	.499 767	.008 77	6.9°
.667 193	.333 812	.010 176	.000 54	.499 760	.008 90	7.0°
.667 208	.333 826	.010 321	.000 56	.499 753	.009 02	7.1°
.667 223	.333 840	.010 467	.000 58	.499 746	.009 15	7.2°
.667 239	.333 854	.010 612	.000 59	.499 739	.009 28	7.3°
.667 255	.333 869	.010 757	.000 61	.499 732	.009 40	7.4°
.667 271	.333 883	.010 902	.000 62	.499 724	.009 53	7.5°
.667 287	.333 898	.011 048	.000 64	.499 717	.009 65	7.6°
.667 303	.333 913	.011 193	.000 66	.499 709	.009 78	7.7°
.667 320	.333 928	.011 338	.000 68	.499 702	.009 91	7.8°
.667 337	.333 944	.011 483	.000 69	.499 694	.010 03	7.9°
.667 354	.333 959	.011 628	.000 71	.499 686	.010 16	8.0°
.667 371	.333 975	.011 773	.000 73	.499 678	.010 29	8.1°
.667 389	.333 991	.011 919	.000 75	.499 670	.010 41	8.2°
.667 407	.334 007	.012 064	.000 76	.499 662	.010 54	8.3°
.667 424	.334 024	.012 209	.000 78	.499 654	.010 66	8.4°
.667 443	.334 040	.012 354	.000 80	.499 646	.010 79	8.5°
.667 461	.334 057	.012 499	.000 82	.499 637	.010 92	8.6°
.667 480	.334 074	.012 644	.000 84	.499 629	.011 04	8.7°
.667 499	.334 091	.012 789	.000 86	.499 620	.011 17	8.8°
.667 518	.334 109	.012 935	.000 88	.499 612	.011 29	8.9°
.667 537	.334 126	.013 080	.000 90	.499 603	.011 42	9.0°
.667 556	.334 144	.013 225	.000 92	.499 594	.011 55	9.1°
.667 576	.334 162	.013 370	.000 94	.499 585	.011 67	9.2°
.667 596	.334 180	.013 515	.000 96	.499 576	.011 80	9.3°
.667 616	.334 198	.013 660	.000 98	.499 567	.011 92	9.4°
.667 636	.334 217	.013 805	.001 00	.499 558	.012 05	9.5°
.667 657	.334 236	.013 950	.001 02	.499 548	.012 17	9.6°
.667 678	.334 255	.014 095	.001 04	.499 539	.012 30	9.7°
.667 699	.334 274	.014 240	.001 07	.499 529	.012 43	9.8°
.667 720	.334 293	.014 385	.001 09	.499 520	.012 55	9.9°
.667 742	.334 313	.014 530	.001 11	.499 510	.012 68	10.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.667 742	.334 313	.014 530	.001 11	.499 510	.012 68	10.0°
.667 763	.334 332	.014 675	.001 13	.499 500	.012 80	10.1°
.667 785	.334 352	.014 820	.001 15	.499 490	.012 93	10.2°
.667 807	.334 373	.014 965	.001 18	.499 480	.013 05	10.3°
.667 830	.334 393	.015 110	.001 20	.499 470	.013 18	10.4°
.667 852	.334 413	.015 255	.001 22	.499 460	.013 30	10.5°
.667 875	.334 434	.015 400	.001 25	.499 449	.013 43	10.6°
.667 898	.334 455	.015 545	.001 27	.499 439	.013 55	10.7°
.667 921	.334 476	.015 690	.001 29	.499 428	.013 68	10.8°
.667 944	.334 498	.015 835	.001 32	.499 418	.013 80	10.9°
.667 968	.334 519	.015 980	.001 34	.499 407	.013 93	11.0°
.667 992	.334 541	.016 125	.001 37	.499 396	.014 05	11.1°
.668 016	.334 563	.016 270	.001 39	.499 385	.014 18	11.2°
.668 040	.334 585	.016 415	.001 42	.499 374	.014 30	11.3°
.668 065	.334 607	.016 560	.001 44	.499 363	.014 43	11.4°
.668 089	.334 630	.016 704	.001 47	.499 352	.014 55	11.5°
.668 114	.334 653	.016 849	.001 49	.499 341	.014 68	11.6°
.668 140	.334 676	.016 994	.001 52	.499 329	.014 80	11.7°
.668 165	.334 699	.017 139	.001 54	.499 318	.014 93	11.8°
.668 191	.334 722	.017 284	.001 57	.499 306	.015 05	11.9°
.668 216	.334 746	.017 429	.001 60	.499 294	.015 18	12.0°
.668 242	.334 769	.017 574	.001 62	.499 283	.015 30	12.1°
.668 269	.334 793	.017 718	.001 65	.499 271	.015 43	12.2°
.668 295	.334 817	.017 863	.001 68	.499 259	.015 55	12.3°
.668 322	.334 842	.018 008	.001 70	.499 247	.015 68	12.4°
.668 349	.334 866	.018 153	.001 73	.499 234	.015 80	12.5°
.668 376	.334 891	.018 298	.001 76	.499 222	.015 92	12.6°
.668 403	.334 916	.018 442	.001 79	.499 210	.016 05	12.7°
.668 431	.334 941	.018 587	.001 81	.499 197	.016 17	12.8°
.668 459	.334 967	.018 732	.001 84	.499 185	.016 30	12.9°
.668 487	.334 992	.018 877	.001 87	.499 172	.016 42	13.0°
.668 515	.335 018	.019 021	.001 90	.499 159	.016 55	13.1°
.668 543	.335 044	.019 166	.001 93	.499 146	.016 67	13.2°
.668 572	.335 070	.019 311	.001 96	.499 133	.016 79	13.3°
.668 601	.335 096	.019 455	.001 99	.499 120	.016 92	13.4°
.668 630	.335 123	.019 600	.002 02	.499 107	.017 04	13.5°
.668 660	.335 150	.019 745	.002 05	.499 094	.017 17	13.6°
.668 689	.335 177	.019 889	.002 08	.499 081	.017 29	13.7°
.668 719	.335 204	.020 034	.002 11	.499 067	.017 41	13.8°
.668 749	.335 231	.020 179	.002 14	.499 054	.017 54	13.9°
.668 779	.335 259	.020 323	.002 17	.499 040	.017 66	14.0°
.668 810	.335 287	.020 468	.002 20	.499 026	.017 78	14.1°
.668 840	.335 315	.020 612	.002 23	.499 012	.017 91	14.2°
.668 871	.335 343	.020 757	.002 26	.498 998	.018 03	14.3°
.668 902	.335 371	.020 902	.002 29	.498 984	.018 15	14.4°
.668 934	.335 400	.021 046	.002 33	.498 970	.018 28	14.5°
.668 965	.335 429	.021 191	.002 36	.498 956	.018 40	14.6°
.668 997	.335 458	.021 335	.002 39	.498 942	.018 52	14.7°
.669 029	.335 487	.021 480	.002 42	.498 927	.018 65	14.8°
.669 061	.335 516	.021 624	.002 45	.498 913	.018 77	14.9°
.669 094	.335 546	.021 769	.002 49	.498 898	.018 89	15.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.669 094	.335 546	.021 769	.002 49	.498 898	.018 89	15.0°
.669 126	.335 576	.021 913	.002 52	.498 883	.019 02	15.1°
.669 159	.335 606	.022 058	.002 55	.498 869	.019 14	15.2°
.669 192	.335 636	.022 202	.002 59	.498 854	.019 26	15.3°
.669 226	.335 666	.022 347	.002 62	.498 839	.019 39	15.4°
.669 259	.335 697	.022 491	.002 65	.498 824	.019 51	15.5°
.669 293	.335 728	.022 635	.002 69	.498 808	.019 63	15.6°
.669 327	.335 759	.022 780	.002 72	.498 793	.019 75	15.7°
.669 361	.335 790	.022 924	.002 76	.498 778	.019 88	15.8°
.669 396	.335 821	.023 069	.002 79	.498 762	.020 00	15.9°
.669 431	.335 853	.023 213	.002 83	.498 747	.020 12	16.0°
.669 465	.335 885	.023 357	.002 86	.498 731	.020 24	16.1°
.669 501	.335 917	.023 502	.002 90	.498 715	.020 37	16.2°
.669 536	.335 949	.023 646	.002 93	.498 699	.020 49	16.3°
.669 572	.335 982	.023 790	.002 97	.498 683	.020 61	16.4°
.669 607	.336 014	.023 935	.003 01	.498 667	.020 73	16.5°
.669 643	.336 047	.024 079	.003 04	.498 651	.020 86	16.6°
.669 680	.336 080	.024 223	.003 08	.498 635	.020 98	16.7°
.669 716	.336 114	.024 367	.003 12	.498 618	.021 10	16.8°
.669 753	.336 147	.024 512	.003 15	.498 602	.021 22	16.9°
.669 790	.336 181	.024 656	.003 19	.498 585	.021 34	17.0°
.669 827	.336 215	.024 800	.003 23	.498 569	.021 46	17.1°
.669 864	.336 249	.024 944	.003 26	.498 552	.021 59	17.2°
.669 902	.336 283	.025 088	.003 30	.498 535	.021 71	17.3°
.669 940	.336 318	.025 233	.003 34	.498 518	.021 83	17.4°
.669 978	.336 353	.025 377	.003 38	.498 501	.021 95	17.5°
.670 016	.336 388	.025 521	.003 42	.498 484	.022 07	17.6°
.670 055	.336 423	.025 665	.003 46	.498 466	.022 19	17.7°
.670 093	.336 458	.025 809	.003 49	.498 449	.022 32	17.8°
.670 132	.336 494	.025 953	.003 53	.498 432	.022 44	17.9°
.670 172	.336 529	.026 097	.003 57	.498 414	.022 56	18.0°
.670 211	.336 565	.026 241	.003 61	.498 397	.022 68	18.1°
.670 251	.336 602	.026 385	.003 65	.498 379	.022 80	18.2°
.670 290	.336 638	.026 529	.003 69	.498 361	.022 92	18.3°
.670 331	.336 675	.026 673	.003 73	.498 343	.023 04	18.4°
.670 371	.336 711	.026 817	.003 77	.498 325	.023 16	18.5°
.670 411	.336 748	.026 961	.003 81	.498 307	.023 28	18.6°
.670 452	.336 786	.027 105	.003 85	.498 289	.023 40	18.7°
.670 493	.336 823	.027 249	.003 89	.498 270	.023 53	18.8°
.670 534	.336 861	.027 393	.003 94	.498 252	.023 65	18.9°
.670 576	.336 899	.027 537	.003 98	.498 233	.023 77	19.0°
.670 618	.336 937	.027 681	.004 02	.498 215	.023 89	19.1°
.670 660	.336 975	.027 825	.004 06	.498 196	.024 01	19.2°
.670 702	.337 013	.027 969	.004 10	.498 177	.024 13	19.3°
.670 744	.337 052	.028 113	.004 14	.498 158	.024 25	19.4°
.670 787	.337 091	.028 257	.004 19	.498 139	.024 37	19.5°
.670 829	.337 130	.028 400	.004 23	.498 120	.024 49	19.6°
.670 873	.337 169	.028 544	.004 27	.498 101	.024 61	19.7°
.670 916	.337 209	.028 688	.004 32	.498 082	.024 73	19.8°
.670 959	.337 249	.028 832	.004 36	.498 062	.024 85	19.9°
.671 003	.337 289	.028 976	.004 40	.498 043	.024 97	20.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

U/L	V/L	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.671 003	.337 289	.028 976	.004 40	.498 043	.024 97	20.0°
.671 047	.337 329	.029 119	.004 45	.498 023	.025 09	20.1°
.671 091	.337 369	.029 263	.004 49	.498 004	.025 21	20.2°
.671 136	.337 410	.029 407	.004 53	.497 984	.025 33	20.3°
.671 180	.337 451	.029 550	.004 58	.497 964	.025 45	20.4°
.671 225	.337 492	.029 694	.004 62	.497 944	.025 57	20.5°
.671 270	.337 533	.029 838	.004 67	.497 924	.025 68	20.6°
.671 316	.337 574	.029 981	.004 71	.497 904	.025 80	20.7°
.671 361	.337 616	.030 125	.004 76	.497 884	.025 92	20.8°
.671 407	.337 658	.030 269	.004 80	.497 863	.026 04	20.9°
.671 453	.337 700	.030 412	.004 85	.497 843	.026 16	21.0°
.671 499	.337 742	.030 556	.004 89	.497 822	.026 28	21.1°
.671 546	.337 785	.030 699	.004 94	.497 802	.026 40	21.2°
.671 593	.337 827	.030 843	.004 99	.497 781	.026 52	21.3°
.671 640	.337 870	.030 986	.005 03	.497 760	.026 64	21.4°
.671 687	.337 913	.031 130	.005 08	.497 739	.026 75	21.5°
.671 734	.337 957	.031 273	.005 13	.497 718	.026 87	21.6°
.671 782	.338 000	.031 417	.005 17	.497 697	.026 99	21.7°
.671 830	.338 044	.031 560	.005 22	.497 676	.027 11	21.8°
.671 878	.338 088	.031 704	.005 27	.497 655	.027 23	21.9°
.671 926	.338 132	.031 847	.005 32	.497 633	.027 35	22.0°
.671 975	.338 177	.031 990	.005 36	.497 612	.027 46	22.1°
.672 024	.338 221	.032 134	.005 41	.497 590	.027 58	22.2°
.672 073	.338 266	.032 277	.005 46	.497 568	.027 70	22.3°
.672 122	.338 311	.032 421	.005 51	.497 547	.027 82	22.4°
.672 172	.338 356	.032 564	.005 56	.497 525	.027 94	22.5°
.672 221	.338 402	.032 707	.005 61	.497 503	.028 05	22.6°
.672 271	.338 448	.032 850	.005 65	.497 481	.028 17	22.7°
.672 322	.338 494	.032 994	.005 70	.497 458	.028 29	22.8°
.672 372	.338 540	.033 137	.005 75	.497 436	.028 41	22.9°
.672 423	.338 586	.033 280	.005 80	.497 414	.028 52	23.0°
.672 474	.338 633	.033 423	.005 85	.497 391	.028 64	23.1°
.672 525	.338 679	.033 567	.005 90	.497 369	.028 76	23.2°
.672 576	.338 726	.033 710	.005 95	.497 346	.028 87	23.3°
.672 628	.338 774	.033 853	.006 00	.497 323	.028 99	23.4°
.672 680	.338 821	.033 996	.006 05	.497 300	.029 11	23.5°
.672 732	.338 869	.034 139	.006 11	.497 277	.029 23	23.6°
.672 784	.338 917	.034 282	.006 16	.497 254	.029 34	23.7°
.672 837	.338 965	.034 425	.006 21	.497 231	.029 46	23.8°
.672 890	.339 013	.034 568	.006 26	.497 208	.029 58	23.9°
.672 943	.339 061	.034 711	.006 31	.497 185	.029 69	24.0°
.672 996	.339 110	.034 854	.006 36	.497 161	.029 81	24.1°
.673 050	.339 159	.034 997	.006 42	.497 138	.029 92	24.2°
.673 103	.339 208	.035 140	.006 47	.497 114	.030 04	24.3°
.673 157	.339 258	.035 283	.006 52	.497 090	.030 16	24.4°
.673 212	.339 307	.035 426	.006 57	.497 067	.030 27	24.5°
.673 266	.339 357	.035 569	.006 63	.497 043	.030 39	24.6°
.673 321	.339 407	.035 712	.006 68	.497 019	.030 50	24.7°
.673 376	.339 457	.035 855	.006 73	.496 995	.030 62	24.8°
.673 431	.339 508	.035 998	.006 79	.496 970	.030 74	24.9°
.673 486	.339 559	.036 140	.006 84	.496 946	.030 85	25.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.673 486	.339 559	.036 140	.006 84	.496 946	.030 85	25.0°
.673 542	.339 610	.036 283	.006 89	.496 922	.030 97	25.1°
.673 598	.339 661	.036 426	.006 95	.496 897	.031 08	25.2°
.673 654	.339 712	.036 569	.007 00	.496 873	.031 20	25.3°
.673 710	.339 764	.036 711	.007 06	.496 848	.031 31	25.4°
.673 767	.339 815	.036 854	.007 11	.496 823	.031 43	25.5°
.673 824	.339 867	.036 997	.007 17	.496 798	.031 54	25.6°
.673 881	.339 920	.037 139	.007 22	.496 773	.031 66	25.7°
.673 938	.339 972	.037 282	.007 28	.496 748	.031 77	25.8°
.673 996	.340 025	.037 425	.007 33	.496 723	.031 89	25.9°
.674 054	.340 078	.037 567	.007 39	.496 698	.032 00	26.0°
.674 112	.340 131	.037 710	.007 44	.496 673	.032 12	26.1°
.674 170	.340 184	.037 852	.007 50	.496 647	.032 23	26.2°
.674 229	.340 238	.037 995	.007 56	.496 622	.032 34	26.3°
.674 287	.340 292	.038 138	.007 61	.496 596	.032 46	26.4°
.674 346	.340 346	.038 280	.007 67	.496 570	.032 57	26.5°
.674 406	.340 400	.038 422	.007 73	.496 544	.032 69	26.6°
.674 465	.340 454	.038 565	.007 78	.496 518	.032 80	26.7°
.674 525	.340 509	.038 707	.007 84	.496 492	.032 91	26.8°
.674 585	.340 564	.038 850	.007 90	.496 466	.033 03	26.9°
.674 645	.340 619	.038 992	.007 96	.496 440	.033 14	27.0°
.674 706	.340 674	.039 135	.008 01	.496 414	.033 25	27.1°
.674 766	.340 730	.039 277	.008 07	.496 387	.033 37	27.2°
.674 827	.340 786	.039 419	.008 13	.496 361	.033 48	27.3°
.674 888	.340 842	.039 561	.008 19	.496 334	.033 59	27.4°
.674 950	.340 898	.039 704	.008 25	.496 308	.033 71	27.5°
.675 012	.340 955	.039 846	.008 31	.496 281	.033 82	27.6°
.675 074	.341 011	.039 988	.008 37	.496 254	.033 93	27.7°
.675 136	.341 068	.040 130	.008 43	.496 227	.034 05	27.8°
.675 198	.341 125	.040 273	.008 49	.496 200	.034 16	27.9°
.675 261	.341 183	.040 415	.008 54	.496 173	.034 27	28.0°
.675 324	.341 240	.040 557	.008 60	.496 145	.034 38	28.1°
.675 387	.341 298	.040 699	.008 66	.496 118	.034 50	28.2°
.675 450	.341 356	.040 841	.008 73	.496 091	.034 61	28.3°
.675 514	.341 415	.040 983	.008 79	.496 063	.034 72	28.4°
.675 578	.341 473	.041 125	.008 85	.496 036	.034 83	28.5°
.675 642	.341 532	.041 267	.008 91	.496 008	.034 94	28.6°
.675 706	.341 591	.041 409	.008 97	.495 980	.035 06	28.7°
.675 771	.341 650	.041 551	.009 03	.495 952	.035 17	28.8°
.675 836	.341 710	.041 693	.009 09	.495 924	.035 28	28.9°
.675 901	.341 769	.041 835	.009 15	.495 896	.035 39	29.0°
.675 966	.341 829	.041 977	.009 21	.495 868	.035 50	29.1°
.676 032	.341 889	.042 119	.009 28	.495 839	.035 61	29.2°
.676 098	.341 950	.042 261	.009 34	.495 811	.035 72	29.3°
.676 164	.342 010	.042 402	.009 40	.495 782	.035 84	29.4°
.676 230	.342 071	.042 544	.009 46	.495 754	.035 95	29.5°
.676 297	.342 132	.042 686	.009 53	.495 725	.036 06	29.6°
.676 364	.342 193	.042 828	.009 59	.495 696	.036 17	29.7°
.676 431	.342 255	.042 970	.009 65	.495 668	.036 28	29.8°
.676 498	.342 316	.043 111	.009 72	.495 639	.036 39	29.9°
.676 566	.342 378	.043 253	.099 78	.495 610	.036 50	30.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.676 566	.342 378	.043 253	.009 78	.495 610	.036 50	30.0°
.676 634	.342 441	.043 395	.009 84	.495 580	.036 61	30.1°
.676 702	.342 503	.043 536	.009 91	.495 551	.036 72	30.2°
.676 770	.342 566	.043 678	.009 97	.495 522	.036 83	30.3°
.676 839	.342 629	.043 819	.010 04	.495 492	.036 94	30.4°
.676 908	.342 692	.043 961	.010 10	.495 463	.037 05	30.5°
.676 977	.342 755	.044 102	.010 17	.495 433	.037 16	30.6°
.677 046	.342 819	.044 244	.010 23	.495 403	.037 27	30.7°
.677 116	.342 882	.044 385	.010 30	.495 374	.037 38	30.8°
.677 186	.342 947	.044 527	.010 36	.495 344	.037 49	30.9°
.677 256	.343 011	.044 668	.010 43	.495 314	.037 60	31.0°
.677 326	.343 075	.044 810	.010 49	.495 284	.037 71	31.1°
.677 397	.343 140	.044 951	.010 56	.495 253	.037 82	31.2°
.677 468	.343 205	.045 092	.010 62	.495 223	.037 92	31.3°
677 539	.343 270	.045 234	.010 69	.495 193	.038 03	31.4°
.677 610	.343 336	.045 375	.010 76	.495 162	.038 14	31.5°
.677 682	.343 401	.045 516	.010 82	.495 132	.038 25	31.6°
.677 754	.343 467	.045 658	.010 89	.495 101	.038 36	31.7°
.677 826	.343 534	.045 799	.010 96	.495 070	.038 47	31.8°
.677 898	.343 600	.045 940	.011 03	.495 039	.038 58	31.9°
.677 971	.343 667	.046 081	.011 09	.495 008	.038 68	32.0°
.678 044	.343 733	.046 222	.011 16	.494 977	.038 79	32.1°
.678 117	.343 801	.046 363	.011 23	.494 946	.038 90	32.2°
.678 190	.343 868	046 504	.011 30	.494 915	.039 01	32.3°
.678 264	.343 936	.046 646	.011 36	.494 884	.039 12	32.4°
.678 338	.344 003	.046 787	.011 43	.494 852	.039 22	32.5°
.678 412	.344 071	.046 928	.011 50	.494 821	.039 33	32.6°
.678 487	.344 140	.047 069	.011 57	.494 789	.039 44	32.7°
.678 561	.344 208	.047 210	.011 64	.494 757	.039 54	32.8°
.678 636	.344 277	.047 350	.011 71	.494 725	.039 65	32.9°
.678 712	.344 346	.047 491	.011 78	.494 694	.039 76	33.0°
.678 787	.344 415	.047 632	.011 85	.494 662	.039 87	33.1°
678 863	.344 485	.047 773	.011 92	.494 629	.039 97	33.2°
678 939	.344 555	.047 914	.011 99	.494 597	.040 08	33.3°
.679 015	.344 625	.048 055	.012 06	.494 565	.040 19	33.4°
679 092	.344 695	.048 195	.012 13	.494 533	.040 29	33.5°
.679 168	.344 765	.048 336	.012 20	.494 500	.040 40	33.6°
.679 245	.344 836	.048 477	.012 27	.494 468	.040 50	33.7°
.679 323	.344 907	.048 618	.012 34	.494 435	.040 61	33.8°
.679 400	.344 978	.048 758	.012 41	.494 402	.040 72	33.9°
.679 478	.345 049	.048 899	.012 48	.494 369	.040 82	34.0°
.679 556	.345 121	.049 039	.012 55	.494 336	.040 93	34.1°
.679 634	.345 193	.049 180	.012 62	.494 303	.041 03	34.2°
.679 713	.345 265	.049 321	.012 69	.494 270	.041 14	34.3°
.679 792	.345 338	.049 461	.012 77	.494 237	.041 24	34.4°
.679 871	.345 410	.049 602	.012 84	.494 204	.041 35	34.5°
.679 950	.345 483	.049 742	.012 91	.494 170	.041 45	34.6°
.680 030	.345 556	.049 882	.012 98	.494 137	.041 56	34.7°
.680 110	.345 630	.050 023	.013 06	.494 103	.041 66	34.8°
.680 190	.345 703	.050 163	.013 13	.494 070	.041 77	34.9°
.680 270	.345 777	.050 304	.013 20	.494 036	.041 87	35.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.680 270	.345 777	.050 304	.013 20	.494 036	.041 87	35.0°
.680 351	.345 851	.050 444	.013 28	.494 002	.041 98	35.1°
.680 432	.345 926	.050 584	.013 35	.493 968	.042 08	35.2°
.680 513	.346 000	.050 724	.013 42	.493 934	.042 18	35.3°
.680 595	.346 075	.050 865	.013 50	.493 900	.042 29	35.4°
.680 677	.346 150	.051 005	.013 57	.493 866	.042 39	35.5°
.680 759	.346 226	.051 145	.013 64	.493 831	.042 49	35.6°
.680 841	.346 301	.051 285	.013 72	.493 797	.042 60	35.7°
.680 923	.346 377	.051 425	.013 79	.493 762	.042 70	35.8°
.681 006	.346 453	.051 565	.013 87	.493 728	.042 81	35.9°
.681 089	.346 529	.051 705	.013 94	.493 693	.042 91	36.0°
.681 173	.346 606	.051 845	.014 02	.493 658	.043 01	36.1°
.681 256	.346 683	.051 985	.014 09	.493 623	.043 11	36.2°
.681 340	.346 760	.052 125	.014 17	.493 588	.043 22	36.3°
.681 424	.346 837	.052 265	.014 24	.493 553	.043 32	36.4°
.681 509	.346 915	.052 405	.014 32	.493 518	.043 42	36.5°
.681 594	.346 993	.052 545	.014 39	.493 483	.043 52	36.6°
.681 679	.347 071	.052 685	.014 47	.493 447	.043 63	36.7°
.681 764	.347 149	.052 825	.014 55	.493 412	.043 73	36.8°
.681 849	.347 228	.052 965	.014 62	.493 376	.043 83	36.9°
.681 935	.347 307	.053 104	.014 70	.493 341	.043 93	37.0°
.682 021	.347 386	.053 244	.014 78	.493 305	.044 03	37.1°
.682 107	.347 465	.053 384	.014 85	.493 269	.044 14	37.2°
.682 194	.347 545	.053 523	.014 93	.493 233	.044 24	37.3°
.682 281	.347 625	.053 663	.015 01	.493 197	.044 34	37.4°
.682 368	.347 705	.053 803	.015 09	.493 161	.044 44	37.5°
.682 455	.347 785	.053 942	.015 16	.493 125	.044 54	37.6°
.682 543	.347 866	.054 082	.015 24	.493 089	.044 64	37.7°
.682 631	.347 947	.054 221	.015 32	.493 052	.044 74	37.8°
.682 719	.348 028	.054 361	.015 40	.493 016	.044 84	37.9°
.682 808	.348 109	.054 500	.015 48	.492 979	.044 94	38.0°
.682 896	.348 191	.054 640	.015 55	.492 943	.045 04	38.1°
.682 986	.348 273	.054 779	.015 63	.492 906	.045 14	38.2°
.683 075	.348 355	.054 919	.015 71	.492 869	.045 24	38.3°
.683 164	.348 437	.055 058	.015 79	.492 832	.045 34	38.4°
.683 254	.348 520	.055 197	.015 87	.492 795	.045 44	38.5°
.683 344	.348 603	.055 336	.015 95	.492 758	.045 54	38.6°
.683 435	.348 686	.055 476	.016 03	.492 721	.045 64	38.7°
.683 526	.348 769	.055 615	.016 11	.492 683	.045 74	38.8°
.683 617	.348 853	.055 754	.016 19	.492 646	.045 84	38.9°
.683 708	.348 937	.055 893	.016 27	.492 608	.045 94	39.0°
.683 799	.349 021	.056 032	.016 35	.492 571	.046 04	39.1°
.683 891	.349 106	.056 171	.016 43	.492 533	.046 14	39.2°
.683 983	.349 190	.056 310	.016 51	.492 495	.046 24	39.3°
.684 076	.349 275	.056 450	.016 59	.492 458	.046 34	39.4°
.684 168	.349 361	.056 589	.016 67	.492 420	.046 43	39.5°
.684 261	.349 446	.056 727	.016 75	.492 382	.046 53	39.6°
.684 354	.349 532	.056 866	.016 83	.492 343	.046 63	39.7°
.684 448	.349 618	.057 005	.016 92	.492 305	.046 73	39.8°
.684 542	.349 704	.057 144	.017 00	.492 267	.046 83	39.9°
.684 636	.349 791	.057 283	.017 08	.492 229	.046 92	40.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

U/L	V/L	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.684 636	.349 791	.057 283	.017 08	.492 229	.046 92	40.0°
.684 730	.349 873	.057 422	.017 16	.492 190	.047 02	40.1°
.684 825	.349 965	.057 561	.017 24	.492 151	.047 12	40.2°
.684 920	.350 052	.057 699	.017 33	.492 113	.047 22	40.3°
.685 015	.350 140	.057 838	.017 41	.492 074	.047 31	40.4°
.685 110	.350 228	.057 977	.017 49	.492 035	.047 41	40.5°
.685 206	.350 316	.058 115	.017 57	.491 996	.047 51	40.6°
.685 302	.350 404	.058 254	.017 66	.491 957	.047 60	40.7°
.685 398	.350 493	.058 393	.017 74	.491 918	.047 70	40.8°
.685 495	.350 582	.058 531	.017 82	.491 879	.047 80	40.9°
.685 592	.350 671	.058 670	.017 91	.491 839	.047 89	41.0°
.685 689	.350 761	.058 808	.017 99	.491 800	.047 99	41.1°
.685 786	.350 851	.058 946	.018 07	.491 760	.048 08	41.2°
.685 884	.350 941	.059 085	.018 16	.491 721	.048 18	41.3°
.685 982	.351 031	.059 223	.018 24	.491 681	.048 28	41.4°
.686 081	.351 121	.059 362	.018 33	.491 641	.048 37	41.5°
.686 179	.351 212	.059 500	.018 41	.491 602	.048 47	41.6°
.686 278	.351 303	.059 638	.018 50	.491 562	.048 56	41.7°
.686 377	.351 395	.059 776	.018 58	.491 521	.048 66	41.8°
.686 477	.351 486	.059 915	.018 67	.491 481	.048 75	41.9°
.686 576	.351 578	.060 053	.018 75	.491 441	.048 85	42.0°
.686 677	.351 671	.060 191	.018 84	.491 401	.048 94	42.1°
.686 777	.351 763	.060 329	.018 92	.491 360	.049 04	42.2°
.686 878	.351 856	.060 467	.019 01	.491 320	.049 13	42.3°
.686 978	.351 949	.060 605	.019 09	.491 279	.049 22	42.4°
.687 080	.352 042	.060 743	.019 18	.491 239	.049 32	42.5°
.687 181	.352 136	.060 881	.019 26	.491 198	.049 41	42.6°
.687 283	.352 229	.061 019	.019 35	.491 157	.049 51	42.7°
.687 385	.352 324	.061 157	.019 44	.491 116	.049 60	42.8°
.687 487	.352 418	.061 295	.019 52	.491 075	.049 69	42.9°
.687 590	.352 513	.061 433	.019 61	.491 034	.049 79	43.0°
.687 693	.352 608	.061 571	.019 70	.490 992	.049 88	43.1°
.687 796	.352 703	.061 708	.019 79	.490 951	.049 97	43.2°
.687 900	.352 798	.061 846	.019 87	.490 910	.050 06	43.3°
.688 004	.352 894	.061 984	.019 96	.490 868	.050 16	43.4°
.688 108	.352 990	.062 122	.020 05	.490 827	.050 25	43.5°
.688 212	.353 086	.062 259	.020 14	.490 785	.050 34	43.6°
.688 317	.353 183	.062 397	.020 22	.490 743	.050 43	43.7°
.688 422	.353 280	.062 534	.020 31	.490 701	.050 53	43.8°
.688 527	.353 377	.062 672	.020 40	.490 659	.050 62	43.9°
.688 633	.353 474	.062 809	.020 49	.490 617	.050 71	44.0°
.688 739	.353 572	.062 947	.020 58	.490 575	.050 80	44.1°
.688 845	.353 670	.063 084	.020 67	.490 533	.050 89	44.2°
.688 952	.353 768	.063 222	.020 75	.490 491	.050 98	44.3°
.689 059	.353 867	.063 359	.020 84	.490 448	.051 08	44.4°
.689 166	.353 966	.063 496	.020 93	.490 406	.051 17	44.5°
.689 273	.354 065	.063 634	.021 02	.490 363	.051 26	44.6°
.689 381	.354 164	.063 771	.021 11	.490 320	.051 35	44.7°
.689 489	.354 264	.063 908	.021 20	.490 278	.051 44	44.8°
.689 597	.354 364	.064 045	.021 29	.490 235	.051 53	44.9°
.689 706	.354 464	.064 182	.021 38	.490 192	.051 62	45.0°

REVISION OF MANUAL.

Your Committee desires to remove an ambiguity in the "Table of Theoretical and Practical Leads" on page 92 of the Manual by inserting the word "theoretical" in the captions of columns II and III.

CONCLUSIONS.

Your Committee recommends for adoption and publication in the Manual:

1. As representing good practice:
   - (a) Tie Plates—General principles to be followed in the design.
   - (b) Specifications for Steel Tie Plates.
   - (c) Specifications for Wrought Iron Tie Plates.
   - (d) Specifications for Malleable Tie Plates.
   - (e) Track Bolts—Facts and general principles to be taken into consideration in the design.
   - (f) Specifications for Track Bolts.
   - (g) Specifications for Spiral Spring Nutlocks.
   - (h) Specifications for Ordinary Track Spikes.
   - (i) Specifications for Screw Spikes.
   - (j) Anti-creepers—General requirements to be met in the design and manufacture.
2. As representing good practice:
   Typical plans of Nos. 8, 11 and 16 main line turnouts.
3. As desirable agencies to obtain a better class of section foremen:
   - (a) The application of the principle of apprenticeship for a defined period during which the rate of pay shall be the same as a laborer, following which those men who show the necessary qualities for foremanship to be given an increase in compensation and the title of assistant foreman. From this position those men should be promoted to that of section foreman.
   - (b) The application of a method of education by periodical instruction in the form of meetings, at which supervising officers should instruct as to practice and encourage discussion between the men.
   - (c) The application where possible of an educational system, such as is being conducted on several of the larger railways, for which articles are written by supervising officers dealing with the best practices, which articles are printed and sent to foremen and assistant foremen free of cost, following which an examination is conducted and promotions depending on the results of such examinations.
4. The "Table of Functions of the Ten-chord Spiral" submitted herewith, as supplementing and completing the table on pages 102-110 of the Manual and superseding the Table on page 111.

5. The headings "W = Length Theoretical Point to Toe" and K = Length Theoretical Point to Heel" in place of "W = Length Point to Toe" and "K = Length Point to Heel" in columns II and III, Table of Theoretical and Practical Switch Leads on page 92 of the Manual.

Your Committee recommends that subjects 2 and 3 be reassigned, the former with instructions as to the features to be studied.

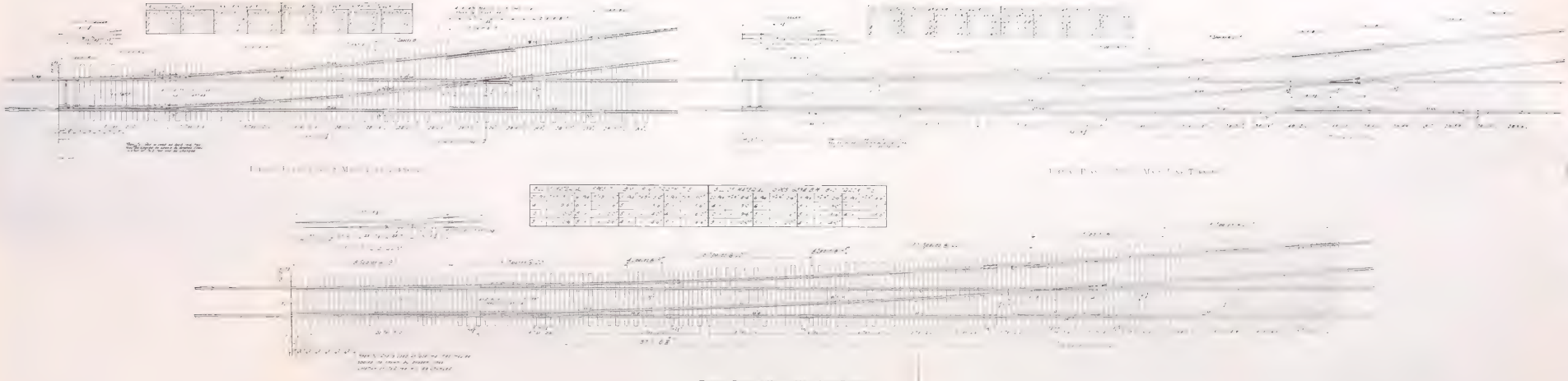
Respectfully submitted,

COMMITTEE ON TRACK.

TYPICAL PLANS OF

NOS. 8, 11 AND 16

MAIN LINE TURNOUTS.



Typical Plan of No. 10 Main Line Turnout

REPORT OF COMMITTEE ON CONSERVATION OF NATURAL RESOURCES.

WILLIAM MCNAB, *Chairman*; W. A. MCGONAGLE,
R. H. AISHTON, G. A. MOUNTAIN,
MOSES BURPEE, W. L. PARK,
F. F. BUSTEED, G. H. WEBB,
A. W. CARPENTER, R. C. YOUNG,
C. H. FISK, *Committee.*

To the Members of the American Railway Engineering Association:

The Committee on Conservation of Natural Resources announces with regret that towards the close of the season its Chairman, Mr. E. O. Faulkner, felt it necessary to be relieved of such office, on account of pressure of official duties, which prevented his giving sufficient attention to the work of the Committee. The members of the Committee take this opportunity of testifying to the high interest Mr. Faulkner has always maintained in the work of Conservation, both as an individual member of this Committee and as its Chairman, and they trust they will have an opportunity of welcoming him back to active work at some future time.

Under the Board's instructions the same subjects as outlined in last year's report were continued for further consideration this year. The members of the Association are asked to note that following the somewhat voluminous investigations, reports and statistics which were collected and formulated last year, bearing on the first two sections of the subject-matter assigned to the Committee, and which are still fresh for consideration, the report this year is intended more to emphasize the fact, that the National Conservation Commissions of the United States and Canada, respectively, are more actively engaged than ever in the various works coming under their purview. Some information supplementary to that given last year, in regard to the Dominion of Canada, has been embodied herein, and will be found interesting.

The fourth National Conservation Congress was held at Indianapolis on the first four days of the month of October. The American Railway Engineering Association had been invited to send delegates, and in the unavoidable absence of both the Chairman and Vice-Chairman, the sessions, in part, were attended by Messrs. R. Ferriday, W. G. Atwood, C. H. Fisk and R. C. Young, the last two members of this Committee. Our representatives reported that at these sessions many problems bearing upon commercial and social economics were discussed, a number of them being specially applicable to railway interests.

One of the most important meetings was conducted along the lines of recommending certain surveys of soil and other resources to be made by the different States, and the recommendation of certain laws

regarding contracts with landowners wishing to go into reforestation of cutover lands, which are fit only for reforestation. It was brought to the attention of this meeting that such laws are now in effect in Louisiana, and are working satisfactorily. These contracts provide for the placing of a nominal valuation on such lands for assessment purposes, until such time as the timber is of an age when it might be harvested.

The Committee has under consideration the fostering of closer relations between it and the officers of the National Commission, as well as with the National Association of State Conservation Commissioners and the Western Forestry and Conservation Association, believing as it does that more officially recognized co-operation with these Associations would be conducive to the attaining of the general objects for which Conservation Commissions were established, and more particularly those features in which the railways are vitally interested.

DOMINION OF CANADA.

TREE PLANTING AND REFORESTATION.

The Forestry Branch, Department of the Interior, has taken the lead in connection with forest planting in Canada. The forest nursery at Indian Head, Sask., has been furnishing a constantly increasing amount of plant material for free distribution among the farmers of the Prairie Provinces. The number of trees and cuttings sent out has increased steadily from 48,000 in 1901 to 2,729,135 in 1912, with a total, all told, of approximately 23,000,000. These trees are scattered in small plantations throughout the settled portions of Alberta, Saskatchewan and Manitoba, so the actual showing is much greater than the number alone would indicate. The force of example will unquestionably cause the rapid spread of the tree-planting idea with the passage of time.

Trees are sought for planting in the prairies chiefly on account of their value as windbreaks. When properly planted and cared for, they afford great protection from wind to crops, stock and buildings, and thus add materially to the value of the farm. A secondary consideration is that of fuel supply, in which, however, the farm woodlot will ultimately prove an important factor.

In addition to supplying trees for distribution to farmers, the Forestry Branch is inaugurating a policy of reforestation on the Dominion Forest Reserves in the Prairie Provinces. Some of these reserves, entirely surrounded by large farming sections, formerly supported a good forest growth, but are now largely denuded as a result of forest fires. The reforestation of these areas is of great economic importance as centers from which the farming population may secure fuel and other wood supplies.

The Department of Agriculture of the Province of Ontario has, since 1904, encouraged the development of farmers' woodlots, through the distribution of trees and cuttings.

The principal tree-planting activity in the Province of Quebec has been in connection with the fixation of certain areas of shifting sands in the eastern portion of the Province. About 300 acres of shifting sands at Lachute have been purchased at $1.00 an acre from farmers who have the privilege of buying it back within the first fifteen years at a price covering the original cost, the cost of reforestation and interest at 4 per cent. The Province, however, guarantees that the cost of such repurchased lands shall not exceed $10.00 an acre. On the area purchased, 40,000 white pine, white spruce, elm and green ash seedlings were planted in 1912. At Berthierville there is a government forest nursery where forestry students are trained each Spring in reforestation.

The Canadian Pacific Railway has done considerable planting along its line in the prairie sections in places where there has been trouble with drifting snow. The intention is to secure a growth of trees which shall replace the numerous snow fences along portions of the line. This Company is also encouraging the planting of trees and shrubs for shelter-belt purposes by farmers who have purchased land from the Company in specified sections of Southern Alberta. One-half the trees required are furnished free, and prizes are offered for the best plantations.

PREVENTION OF FIRES FROM RAILWAYS.

On May 22, 1912, the Board of Railway Commissioners for Canada issued an Order requiring railways subject to its jurisdiction to take certain measures for the prevention of forest and grass fires along their lines. This Order, a copy of which is appended hereto, included in a slightly modified form provisions contained in former Orders for the use and inspection of fire-protective appliances on locomotives, the construction of fire-guards in the Prairie Provinces and the non-use of lignite coal. In addition, provision was made for the appointment of a Chief Fire Inspector, who is given authority to prescribe special patrols to be maintained by the railway companies where such action is considered necessary. The regulation of the burning of inflammable material along rights-of-way during the fire season is also provided for. Railway employes are required to report and extinguish railway fires, and any fires starting or burning within 300 feet of the track are presumed to have started from the railway, unless proof to the contrary is furnished.

Regulations of a similar nature have been issued by the Public Utilities Commission of the Province of Quebec, applicable to provincially chartered railways. The prevention of railway fires along provincially chartered lines in British Columbia, through the adoption of similar measures, is provided for by the new Forest Act, which became law early in 1912.

ORDER OF THE BOARD OF RAILWAY COMMISSIONERS FOR CANADA, DESCRIBING REGULATIONS TO BE ADOPTED BY RAILWAY COMPANIES FOR THE PREVENTION OF FIRES.

2. Until further order, every railway subject to the legislative authority of the Parliament of Canada, under construction, or being operated by steam, shall, unless exempted by a special order of the Board, cause every locomotive engine used on the said railway, or portion of railway, being constructed or operated by it, to be fitted and kept fitted with netting mesh as hereinafter set forth, namely:

(a) On every engine equipped with an extension smoke box, the mesh shall be not larger than 2½x2½ per inch of No. 10 Birmingham wire gage, and shall be placed in the smoke box so as to extend completely over the aperture through which the smoke ascends, the openings of the said mesh not to exceed a quarter of an inch and one sixty-fourth (that is, seventeen sixty-fourths) of an inch to the square.

(b) On every engine equipped with a diamond stack, the mesh shall be not more than 3x3 per inch of No. 10 Birmingham wire gage, and shall be placed at the flare of the diamond of the stack, so as to cover the same completely, the openings of the said mesh not to exceed three-sixteenths and one sixty-fourth (that is, thirteen sixty-fourths) of an inch to the square.

3. Every such railway company shall cause—

(a) The openings of the ashpans on every locomotive engine used on the railway, or portion of railway, operated or being constructed by it, to be covered, when practicable, with heavy sheet-iron dampers; and, if not practicable, with screen netting dampers 2½x2½ per inch of No. 10 Birmingham wire gage, such dampers to be fastened either by a heavy spring or by a split cotter and pins, or by such other method as may be approved by the board.

(b) Overflow pipes from lifting injectors, or from water pipes, from injector-delivery pipe, or from boiler, to be put into the front and back part of the ash pans and used from the first day of April to the first day of November, or during such portion of this period as the Board may prescribe for wetting ashpans.

4. Every such railway company shall provide inspectors at terminal or division points where its locomotive engines are housed and repaired, and cause them, in addition to the duties to which they may be assigned by the officials of the railway companies in charge of such terminal or division points—

(a) To examine, at least once a week—
  (1) The nettings;
  (2) Dead plates;
  (3) Ash pans;
  (4) Dampers;
  (5) Slides; and
  (6) Any other fire-protective appliance or appliances used on any and all engines running into the said terminal or divisional points.

(b) To keep a record of every inspection in a book to be furnished by the railway company for the purpose, showing—
  (1) The numbers of the engines inspected;
  (2) The date and hour of day of such inspection;
  (3) The condition of the said fire-protective appliances and arrangements; and
  (4) A record of repairs made in any of the above-mentioned fire-protective appliances.

The said book to be open for inspection by the Chief Fire Inspector or other authorized officer of the Board.

(c) In case any of the said fire-protective appliances in any locomotive are found to be defective, said locomotive shall be removed from service and shall not (during said prescribed period) be returned to service, unless and until such defects are remedied.

(d) Every such railway company shall also appoint one or more Special Inspectors, as may be needed, whose duties shall be to make an independent examination of the fire-protective appliances on all the locomotives of such company, at least once each month, and report the condition of such fire-protective appliances direct to the Chief Mechanical Officer of the railway company, or other chief officer held responsible for the condition of the motive power of the said company.

5. Any authorized officer of the Board shall have power to inspect at any time any and all locomotives, and may remove from service any locomotive which is found to be defective in the said fire-protective appliances; and any such locomotive so removed from service, shall not (during the said prescribed period) be returned to service unless and until such defects are remedied.

6. No employe of any such railway company shall—

(a) Do, or in any way cause, damage to the netting on the engine smokestack or to the netting in the front end of such engine;

(b) Open the back dampers of such engine while running ahead, or the front dampers while running tender first;

(c) Or otherwise do or cause damage or injury to any of the fire-protective appliances on the said engine.

7. No such railway company shall permit fire, live coals, or ashes, to be deposited upon its tracks or right-of-way outside of the yard limits, unless they are extinguished immediately thereafter.

8. No such railway company shall burn lignite coal on its locomotive engines as fuel for transportation purposes, unless otherwise ordered by the Board—lignite coal consisting of and including all varieties of coal between peat and bituminous, with a carbon-hydrogen ratio of 11.2 or less, such ratio being based on analysis of air-dried coal.

9. Every such railway company shall establish and maintain fire-guards along the route of its railway as the Chief Fire Inspector may prescribe. The nature, extent, establishment and maintenance of such fire-guards shall be determined as follows:

(a) The Chief Fire Inspector shall each year prepare and submit to every such railway company a statement of the measures necessary for establishing and maintaining the routes of such railways in a condition safe from fire, so far as may be practicable.

(b) Said measures may provide for the cutting and disposal by fire, or otherwise, of all or any growth of an inflammable character, and the burning or other disposal of debris and litter on a strip of sufficient width on one or both sides of the track; the plowing or digging of land in strips of sufficient width on one or both sides of the track; and such other work as may, under the existing local conditions and at reasonable expense, tend to reduce to a minimum the occurrence and spread of fire.

(c) Said statements of the Chief Fire Inspector shall be so arranged as to deal with and prescribe measures for each separate portion of such railway upon and adjacent to which the fire risk calls for specific treatment. The intention shall be to adjust the protective measures to the local conditions and to make the expense proportionate to the fire risk and the possible damage.

(d) Said statements of the Chief Fire Inspector shall prescribe dates on or within which the foregoing protective measures shall be

commenced and completed, and the fire-guards maintained in a clean and safe condition.

(e) No such railway company shall permit its employes, agents, or contractors to enter upon land under cultivation, to construct fire-guards, without the consent of the owner or occupant of such land.

(f) Wherever the owner or occupant of such land objects to the construction of fire-guards, on the ground that the said construction would involve unreasonable loss or damage to property, the company shall *at once* refer the matter to the Board, giving full particulars thereof, and shall in the meantime refrain from proceeding with the work.

(g) No agent, employe, or contractor of any such railway company, shall permit gates to be left open or to cut or leave fences down whereby stock or crops may be injured, or do any other unnecessary damage to property, in the construction of fire-guards.

10. In carrying out the provisions of Section 297 of the Railway Act, which enacts that "the company shall at all times maintain and keep its right-of-way free from dead or dry grass, weeds, and other unnecessary combustible matter," no such railway company or its agents, employes, or contractors, shall, between the first day of April and the first day of November, burn or cause to be burned any ties, cuttings, debris or litter upon or near its right-of-way, except under such supervision as will prevent such fires from spreading beyond the strip being cleared. The Chief Fire Inspector or other authorized officer of the Board may require that no such burning be done along specified portions of the line of any such railway, except with the written permission or under the direction of the Chief Fire Inspector or other authorized officer of the Board.

11. The railway company shall provide and maintain a force of fire-rangers fit and sufficient for efficient patrol and fire-fighting duty during the period from the first day of April to the first day of November of each year; and the methods of such force shall be subject to the supervision and direction of the Chief Fire Inspector or other authorized officer of the Board.

12. The Chief Fire Inspector shall, each year, prepare and submit to each and every railway company a statement of the measures such railway companies shall take for the establishment and maintenance of said specially organized force. Said statements, among other matters, may provide for—

(a) The number of men to be employed and the said force, their location and general duties, and the methods and frequency of the patrol;

(b) The acquisition and location of necessary equipment for transporting the said force from place to place, and the acquisition and distribution of suitable fire-fighting tools; and

(c) Any other measures which are considered by him to be essential for the immediate control of fire and may be adopted at reasonable expense.

13. Whenever and while all the locomotive engines used upon any such railway, or any portion of it, burn nothing but oil as fuel, during the aforesaid prescribed period, under such conditions as the Board may approve, the Board will relieve the said railway of such portions of these regulations as may seem to it safe and expedient.

14. The sectionmen and other employes, agents, and contractors of every such railway company shall take measures to report and extinguish fires on or near the right-of-way, as follows:

(a) Conductors, engineers, or trainmen who discover or receive notice of the existence and location of a fire burning upon or near the right-of-way, or of a fire which threatens land adjacent to the right-of-way, shall report the same to the agent or persons in charge at the next point at which there shall be communication by telegraph or tele-

phone, and to the first section employes passed. Notice of such fire shall also be given immediately by a system of warning whistles.

(b) It shall be the duty of the agent or person so informed to notify immediately the nearest forest officer and the nearest section employes of the railway, of the existence and location of such fire.

(c) When fire is discovered, presumably started by the railway, such sectionmen or other employes of the railway as are available shall, either independent or at the request of any authorized forest officer, proceed to the fire immediately and take action to extinguish it; provided such sectionmen or other employes are not at the time engaged in labors immediately necessary to the safety of trains.

(d) In case the sectionmen or other employes available are not a sufficient force to extinguish the fire promptly, the railway company shall, either independently or at the request of any authorized forest officer, employ such other laborers as may be necessary to extinguish the fire; and as soon as a sufficient number of men, other than the sectionmen and regular employes, are obtained, the sectionmen and other regular employes shall be allowed to resume their regular duties.

Note.—Any fire starting or burning within 300 feet of the railway track, shall be presumed to have started from the railway, unless proof to the contrary is furnished.

15. Every such railway company shall give particular instructions to its employes in relation to the foregoing regulations, and shall cause appropriate notices to be posted at all stations along its lines of railway.

16. Every such railway company allowing or permitting the violation of, or in any respect, contravening or failing to obey any of the foregoing regulations, shall, in addition to any other liability which the said company may have incurred, be subject to a penalty of one hundred dollars for every such offence.

17. If any employe or other person included in the said regulations, fails or neglects to obey the same, or any of them, he shall, in addition to any other liability which he may have incurred, be subject to a penalty of twenty-five dollars for every such offence.

COAL RESOURCES.

As a result of an investigation by the Commission of Conservation it was found that there was in Saskatchewan, Alberta and British Columbia, a considerable waste of slack coal which had been mined and brought to the surface. This waste of unmarketable slack coal varies from 10 to 35 per cent. of the output. In Saskatchewan, 10 to 25 per cent. of the output from the mines is slack coal, which is dumped on the ground and wasted. In the vicinity of Estevan, 10 to 12 per cent. of the output from some of the larger mines is dumped on the prairie and burned. It is necessary to remove this coal (lignite) from the mine plant, as it readily ignites by spontaneous combustion.

The waste of slack coal varies from 10 to 12 per cent. in the Lethbridge district, and from 20 to 35 per cent in the Edmonton district. In the Crowsnest Pass district, in Alberta and British Columbia, the coal is of better grade and some of the slack is marketable; the remainder is made into coke in beehive coke ovens. At Bankhead, briquettes are made from the slack coal. On Vancouver Island, some of the large producing mines waste from 10 to 15 per cent. of their output as slack coal, and, unfortunately, it is generally dumped into the sea. The high freight rates make it impossible to market this slack at a profit.

In order to save to the community what amounts to more than 15 per cent. of the total output of coal, besides the low-grade coal which is often left in the mine, it was suggested that the following studies be made:

(1) To ascertain the price of coal in different parts of the West, and which portions of the country are supplied with coal from the different mining centers, also the prices of coal in Canada and the freight rates on the same from the mines to the market.

(2) Owing to the necessity of obtaining a suitable domestic fuel and cheap power for the Prairie Provinces, it is desirable that investigations be carried on with a view to utilizing the lignites which underlie the greater portion of these provinces. In this connection, it is of interest to know that the United States Bureau of Mines has demonstrated that suitable briquettes can be made from low-grade lignites. The Bureau has also shown that many fuels of such low-grade as to be practically valueless for steaming purposes, including slack coal, bone coal, and lignite, may be economically converted into producer gas and may thus generate sufficient power to render them of high commercial value.

PEAT DEPOSITS.

The Fuel Testing Division of the Mines Branch, Ottawa, has recently carried on experiments on the utilization of peat fuel for the production of power. The tests were carried on in a 60-H.P. double-zone "Korting" peat gas producer, and a 60-H.P., 4-stroke cycle, single-acting "Korting" gas engine. The results of this investigation are published in a report on the Utilization of Peat Fuel for the Production of Power, and are as follows:

RELIABILITY.

The peat producer-gas power plant, as now constructed, may be pronounced thoroughly reliable. Its operation may be carried on continuously for a week or more without having to shut down for the purpose of cleaning the valves of the engine. The engine has been operated for a period of 150 hours without removing either the admission or mixing valves for cleaning.

It should not be found necessary, in commercial practice, to remove the piston for the purpose of cleaning, more than once in six months.

The operation of the producer is uniform, and the gas delivered to the engine varies only slightly during a ten-hours' run. The removal of ashes, and the cleaning of the fires, can be done without interfering with the operation of the engine, due to a change in the quality of the gas.

ATTENDANCE.

A peat-producer-gas-power plant of the size installed in the Fuel Testing Station can safely be left in the hands of an intelligent laborer after he has received, for a week or so, instructions in the handling

of the plant, from a competent engineer. The services of only one man are required to run this plant when it is operated on day-shift work only.

CLEANING OF GAS PIPES, MAINS, VALVES, ETC.

It is recommended that the gas pipes leading from the producer to the cleaning system and the tar filter be cleaned once a week, if possible, when the plant is run ten hours a day during the working days of the year. If this is done, very little will be required to keep the plant in good condition. The admission and mixing valves of the engine will not require cleaning for two weeks or more.

FUEL CONSUMPTION.

The consumption of fuel per brake-horsepower hour—including stand-by losses—is for full load, 1.7 lbs. of dry peat, or 2.3 lbs. of peat containing 25 per cent. moisture; for three-fourths load, the fuel consumption—including stand-by losses—is 2.1 lbs. of dry peat, or 2.8 lbs. of peat containing 25 per cent. moisture.

COST OF FUEL.

In estimating fuel costs, the assumption is made that peat with a moisture content of 25 per cent. can be delivered to the producer for $2 per ton. In order, however, to take advantage of this, or a lower cost for fuel, the power plant will have to be situated at or near the bog where the peat fuel is manufactured. For small plants of the type and capacity described in the foregoing remarks this might not prove feasible in many cases, but will prove entirely feasible and practicable when the plants are of large capacity and when the energy developed is transmitted, in the form of electricity, to neighboring towns and villages, for lighting, power and other purposes.

Since the fuel burned in the producer does not require to be of the best quality, the fuel cost may be considerably reduced, since the broken peat bricks and considerable fines—which always occur in the manufacture of peat and otherwise, represent a loss—can be efficiently utilized in the producer. Assuming, however, that peat can be delivered to the plant for $2 per ton, and that the plant is run with a power-factor of 75 per cent. for 3,000 hours, the fuel costs would be $8.40 per B.H.P. year, including stand-by losses.

PLANT COST.

The first cost of a plant of this type, in comparison with that of other types, should be left for the consideration of those interested in particular cases, by obtaining competitive prices from manufacturers. Local conditions, capacity of plant, etc., changes the first cost so considerably that any figures quoted here might prove misleading.

BY-PRODUCT RECOVERY PLANTS.

In various plants at present utilizing peat for the production of power, the net cost of developing power is considerably reduced by the sale

of sulphate of ammonia and tar, which are recovered as by-products. This recovery is attempted only in plants of larger size than the one used.

NATURAL GAS IN CANADA.

The production of natural gas in Canada has increased in value nearly thirteen-fold during the last nineteen years, and of the total amount the Province of Ontario produced about 94 per cent. Steps were taken by the Ontario Government in 1907 to prevent the waste of natural gas, and a law was passed levying a tax of two cents per 1,000 ft., with a rebate of 90 per cent. when the gas is used in Canada. This provision has been very effective. In Alberta little provision has as yet been made for the plugging of the gas wells, and many millions of cubic feet have therefore been wasted annually and extended areas have been more or less drained.

In 1912 there has been considerable natural gas developments in New Brunswick and Alberta. In New Brunswick the city of Moncton is supplied from one of seventeen wells situated in Albert County, about 11 miles distant.

In Alberta, the Canadian Western Natural Gas, Light, Heat and Power Company, Limited, has completed 15 natural gas wells in the vicinity of Bow Island, Alberta, from which gas is now being piped to Calgary, a distance of 175 miles. In addition to supplying Calgary, the company has branch lines to Lethbridge, MacLeod, Granum, Nanton, Claresholm, Brooks and Okotoks.

PETROLEUM RESOURCES.

The production of crude petroleum comes almost entirely from the Province of Ontario. The production of Canada in 1911 was made up of 291,092 barrels, or 288,631 barrels from Ontario and 2,461 barrels from New Brunswick. The following table gives the production of oil in Canada since 1901, in barrels of 35 gallons, together with the total value, and average price per barrel:

PRODUCTION OF CRUDE PETROLEUM IN CANADA, 1901-1911.

YEAR	Barrels of 35 gallons.	Value.	Average price per barrel.
1901	622,392	$1,008,275	$1.620
1902	530,624	951,190	1.792
1903	486,637	1,048,974	2.155
1904	503,474	935,895	1.858
1905	634,095	856,028	1.350
1906	569,753	761,760	1.337
1907	788,872	1,057,088	1.340
1908	527,987	747,102	1.415
1909	420,755	559,604	1.329
1910	315,895	388,550	1.230
1911	291,092	357,073	1.226

There has been a diminution in the output of the oil fields of Ontario, and the present production is about 46.3 per cent. of what it was in 1901, and, if the falling off continues at the same rate, the supply of domestic petroleum will tend to become relatively insignificant unless new reservoirs are opened up.

The oil production of New Brunswick increased from 95 barrels in 1909 to 2,461 barrels in 1911. The oil production here is really incident to natural gas production.

The total imports of petrolum oils, crude and refined, in 1911, was 116,892,689 gallons, valued at $6,009,730, in addition to 1,959,787 pounds of wax and candles, valued at $106,424.

PETROLEUM RESOURCES.

While the actual petroleum resources of Canada are comparatively small, nevertheless, the potential resources are considerable. In New Brunswick and Nova Scotia there are enormous deposits of oil shales which are valuable as a source of oil. On an average these shales will give a higher yield of crude oil per ton than the oil shales worked so extensively in Scotland.

In the vicinity of Fort McMurray and Fort McKay, on the Athabaska River, Alberta, there are enormous deposits of tar sands. The bitumen in the tar sands is the residue from evaporated petroleum. It has been estimated that there is 6½ cubic miles of solid bitumen in the tar sands exposed on this river.

Although enormous quantities of oil have evaported from this district, nevertheless it seems probable that accumulations of petroleum may exist in places where the geological structure was such as to prevent its escape. This is also exemplified by the fact that natural gas occurs in quantity in districts where the tar sands are capped by overlying measures.

If large quantities of petroleum were discovered in Alberta it would be a factor of great importance to the railway interests which operate in the Rocky Mountains and Jasper Parks and the forest areas in British Columbia and Alberta.

The Canadian Pacific Railway is now using oil-burning engines on its main line betwen Kamloops and Field, in British Columbia. The Grand Trunk Pacific and some of the Canadian Pacific coast steamships also burn oil, and other boats are being changed from coal-burners to oil-burners. The oil is at present obtained from the California oil fields. If supplies can be obtained at the prices now prevailing, its use will be very largely extended. Its cleanliness, the greatly decreased smoke, the decrease in the number of firemen required, the economy, particularly in intermittent service, the increased efficiency—two boilers with oil, in steamship service, giving the same steam as three with coal—and other considerations, make it an almost ideal fuel.

Respectfully submitted,

COMMITTEE ON CONSERVATION OF NATURAL RESOURCES.

REPORT OF COMMITTEE II—ON BALLAST.

H. E. Hale, *Chairman;*
W. J. Bergen,
A. F. Blaess,
L. W. Baldwin,
T. C. Burpee,
O. H. Crittenden,
F. T. Darrow,
J. M. Egan,
T. W. Fatherson,
H. L. Gordon,
G. H. Harris,
J. M. Meade, *Vice-Chairman;*
C. C. Hill,
S. A. Jordan,
William McNab,
A. S. More,
J. V. Neubert,
S. B. Rice,
E. V. Smith,
F. J. Stimson,
S. N. Williams,
Committee.

To the Members of the American Railway Engineering Association:

The Ballast Committee held two meetings of the Committee as a whole (with other meetings of the Sub-Committees) as follows:

First meeting at Chicago, Friday, September 6, 1912, at which there were present: H. E. Hale, Chairman; J. M. Meade, Vice-Chairman; S. N. Williams, S. B. Rice, C. C. Hill, F. J. Stimson.

Second meeting at Chicago, Friday, December 6, 1912, at which there were present: H. E. Hale, Chairman; J. M. Meade, Vice-Chairman; W. J. Bergen, S. N. Williams, S. B. Rice, G. H. Harris, S. A. Jordan, H. L. Gordon, Wm. McNab, F. J. Stimson.

The work assigned to the Ballast Committee was divided between three Sub-Committees, as follows:

(A) REPORT ON PROPER DEPTH OF BALLAST OF VARIOUS KINDS TO INSURE UNIFORM DISTRIBUTION OF LOADS ON ROADWAY, CONFERRING WITH COMMITTEE ON ROADWAY.

Sub-Committee: H. E. Hale, Chairman; W. J. Bergen, T. C. Burpee, O. H. Crittenden, J. M. Egan, T. W. Fatherson, G. H. Harris, C. C. Hill, A. S. More, E. V. Smith, F. J. Stimson, Wm. McNab.

In last year's report on this subject your Committee had as a basis for its report several reliable and thorough tests, such as the tests made by the Pennsylvania Railroad at Altoona and by Director Schubert, of the German Railways, in Germany, and on the information obtained for these tests your Committee drew its conclusions and made its recommendations to the Association, which recommendations covered the subject as far as the information permitted. These recommendations were printed on page 97, in the report of 1912, and adopted by the Association, but the subject in a modified form was again referred to the Committee.

The tests on which the Committee based their conclusions have been conducted largely under artificial conditions, which were designed to be, as nearly as possible, those which actually existed in the track under regular traffic, but under the circumstances it was impossible to absolutely reproduce conditions existing in track under regular traffic.

Careful search has been made to obtain reports or results of tests on this subject, both in foreign and American engineering papers, and this search has been practically without result. It therefore appears that if further investigation or report is to be made by your Committee, it must be based on new tests, which should be made in track under regular traffic—preferably heavy traffic.

Discussion of this subject by the Committee with other members of the Association has led the Committee to believe that many members of the Association feel that a further test in track under regular traffic is desirable, and to place this before the Association in tangible form, your Committee has worked out the following proposed test:

PROPOSED TEST TO DETERMINE PROPER DEPTH OF BALLAST OF VARIOUS KINDS TO INSURE UNIFORM DISTRIBUTION OF LOADS ON THE ROADWAY.

(1) Select a stretch of track on clay roadbed, under heavy traffic, where trouble has been experienced with clay working up between the ties.

(2) Excavate roadbed to a uniform depth of 30 in. below the bottom of the ties, for a space of two rail lengths; prepare the adjacent rail lengths in the same manner, decreasing the depth 3 in. under each successive two rails, until the bed is 12 in. below the bottom of the tie (14 rail lengths).

(3) Place on this bed a thin layer of fibrous material, such as hay, to make a well-defined separation between roadbed and ballast.

(4) Place stone ballast on bed to the above-mentioned depths, tamp well, and put track in good line and surface.

(5) Make note of tie spacing, width of ties, keep accurate levels and record of amount of time spent on surfacing various parts of track, also keep record of axle loads and amount of traffic. Take photographs at regular intervals to show deformation of roadbed.

(6) Make similar test for gravel and similar for ballast section, having a sub-ballast of gravel equal to one-half the total depth and a top ballast of stone equal to one-half the total depth of ballast.

(7) The estimated cost of this test is as follows:

(a)	Cost of material (stone), 500 yds. at 80 cents	$ 400.00
(b)	Labor, preparing track and widening bank, where necessary, at $30.00 per rail (14 rails per test)	420.00
(c)	Labor, inspecting, six inspections at $2.00 per rail	170.00
(d)	Line and surface to be paid for by railway owning track, at regular maintenance charge	00.00
	Total for one test	$ 990.00
	Three tests	$3,000.00

CONCLUSION.

Your Committee recommends that the above test be made under the direction and supervision of the Ballast Committee, and that same be financed by the Association or some railroad or railroads. The location for the test to be arranged for by the Committee with a railroad that would be willing to have this test made in their main tracks under heavy, regular traffic.

(B) CONTINUE STUDY OF PHYSICAL TESTS OF STONE FOR BALLAST.

Sub-Committee: S. A. Jordan, Chairman; S. B. Rice, H. L. Gordon, J. V. Neubert.

Your Committee has previously recommended certain physical tests of stone for ballast, with full description of the tests and how to have same made by the United States Government at Washington. Further investigations by the Committee this year have resulted in practically no additional information except a paper read at the Sixth Congress in New York of the International Society for Testing Materials by A. T. Goldbeck and F. M. Jackson, which quoted, in part, the table and data given in the American Railway Engineering Association report of 1912 and practically give the same information as given in our reports.

The table showing results of physical test of stone for ballast, as presented to the Association last year, has been checked, and the various railroads represented have advised that they had nothing further to add to the table. This table is considered by your Committee to be a very good guide for comparing stone from various quarries when selecting same for ballast.

The further consideration of the physical tests of stone for ballast by the Committee resulted in their recommending the physical tests as a guide only in the specifications for stone ballast, and it is recommended that the following note be added in the Manual to the specifications for stone ballast.

CONCLUSION.

NOTE—*"Attention is called to the physical tests of stone for ballast printed in the Manual, page 47, which are recommended as a guide, in connection with these specifications."*

After further consideration of this subject, your Committee feels that the information, as at present printed in the Manual in regard to the physical tests of stone for ballast, was not clear to some of those who were not familiar with the subject, and it is recommended that the information given in the Manual on this subject on page 47, under the heading of "Physical Tests of Stone for Ballast," be changed to read as follows (portion in italics is additional):

"It is recommended that the following be used for physical tests of stone ballast. *Other things being equal the maximum or minimum results as indicated will govern in selecting stone for ballast:*

(a) Weight per cubic foot—*Maximum.*
(b) Water absorption in pounds per cubic foot—*Minimum.*
(c) Per cent. of wear—*Minimum.*
(d) Hardness—*Maximum.*
(e) Toughness—*Maximum.*
(f) Cementing value—*Minimum.*
(g) Compression test—*Maximum.*"

For the description of the physical tests of stone for ballast as recommended by the Association and full instructions as to how the samples should be obtained and shipped to the Government for test (test made free of charge by the United States Government), see Proceedings of the American Railway Engineering Association, Vol. 11, Part 2, pp. 910-914, and report of Ballast Committee of 1912. If blue prints of the machine used in making the tests are desired, they can be obtained from the Department of Agriculture, United States Government, Washington, D. C.

SIZE OF STONE BALLAST.

Your Committee wishes to present to the Association a copy of a report of a test made by the Pennsylvania Railroad in regard to the first cost of putting in ballast and maintaining same for various sizes of stone ballast; the report is given below.

SIZES OF BALLAST.

Investigation conducted by the Pennsylvania Company between August, 1899, and October, 1903, inclusive, record of experimental tests of three different sizes of broken stone ballast:

	Size of Stone Ballast.		
	¾ in.	1½ in.	2½ in.
Double track ballast, feet	5,280	5,211	5,280
Double track ballast, miles	1.0	0.987	1.0
Stone ballast used, cars	228	171	198
Stone ballast used, tons	6,200.5	4,651.8	4,947.9
Cars stone per mile double track	228	173	198
Tons stone per mile double track	6,200	4,713	4,948
Linear feet double track to 1 car	23.1	30.5	26.7
Linear feet double track to 1 ton	.85	1.12	1.07
Average depth ballast under ties	7.25 in.	6.5 in.	6.75 in.
Total first cost of ballast, freight, unloading, putting in tracks, lining and surfacing, etc.	$7,911.60	$5,633.51	$5,263.92
Average cost per foot double track	1.50	1.08	.997
Average cost per mile double track	7,911.60	5,708.10	5,263.92
Cost ballast per ton at quarry	60–70c	60–68c	58–69c
Average cost of maintenance for period of 51 months, per mile	94.66	84.94	82.13

CONCLUSION.

After considering this information, your Committee does not wish to make any change in the size of stone for ballast, as now recommended in the Manual.

REPORT OF TEST ON GRAVEL BALLAST RECEIVED FROM VARIOUS RAILROADS SHOWING PERCENTAGES OF SAND, GRAVEL DUST, ETC., AS DELIVERED FROM VARIOUS PITS ALONG THEIR LINES.

Tests Supervised by H. B. McFarland, Engineer of Tests, under direction of J. M. Meade, Engineer Eastern Lines, Atchison, Topeka & Santa Fe Ry., Topeka, Kansas.

Railroad	Pit	Weight in Lbs. per Cu. Yd.		Percentages				Remarks
		As Received	Dried	Moisture	Gravel	Sand	Dust	
Atchison, Topeka & Santa Fe Ry	Chillicothe	2,988.00	2,975.00	0.44	54.0	39.3	6.7	A. T. & S. F.: Used as it comes from the pit. Gives good results and very satisfactory. 12" under the ties. Dressed level.
Chicago, Burlington & Quincy	O'Neil	2,680.00	2,659.00	0.75	19.0	61.8	19.2	C. B. & Q.: Reports show gravel used as it comes from the pits. Makes excellent track. Binds well and easily worked.
Chicago, Burlington & Quincy	Denver	3,216.00	3,197.00	0.58	67.0	29.2	3.8	
Chicago, Burlington & Quincy	Atchison	2,856.00	2,814.00	1.47	66.0	28.7	5.3	
Chicago, Burlington & Quincy	Peetz	2,878.00	2,854.00	0.82	58.0	38.9	3.1	
Chicago, Burlington & Quincy	Ballantine	3,096.00	3,068.00	0.90	59.0	18.9	22.1	
Chicago, Rock Island & Pacific	Graettinger	3,242.00	3,214.00	0.82	63.0	20.4	16.6	C. R. I. & P.: Used as it comes from the pits. Considered fair ballast.
Chicago, Rock Island & Pacific	St. Louis	3,041.00	3,026.00	0.50	94.0	5.3	0.7	
Grand Rapids & Indiana	Kalamazoo	3,411.00	3,403.00	0.23	77.0	18.0	5.0	G. R. & I.: Used as it comes form the pits. Kalamazoo pit considered first-class. Belmont pit considered good.
Grand Rapids & Indiana	Belmont	3,293.00	3,279.00	0.44	64.0	28.7	7.3	
Illinois Central	Glenville	3,134.00	3,118.00	0.50	38.0	51.3	10.7	I. C.: Used as it comes from the pits. Considered fair ballast.
Illinois Central	Riverton	3,345.00	3,313.00	0.95	58.0	37.8	4.2	
Illinois Central	Forreston	3,181.00	3,162.00	0.61	82.0	13.8	4.2	
Illinois Central	Cherokee	2,543.00	2,532.00	0.44	81.0	15.8	3.2	
Missouri Pacific	Ft. Gibson	2,682.00	2,669.00	0.49	91.0	6.5	2.5	Mo. Pac.: Used as it comes from the pits. Bethel pit not considered very good ballast. Pit abandoned. Ft. Gibson pit considered fair; would be better if it contained more sand.
Missouri Pacific	Bethel	3,034.00	2,985.00	1.60	76.0	20.9	3.1	
New York Central & Hudson River	Yosts	2,856.00	2,846.00	0.34	62.0	33.9	4.1	N. Y. C. & H. R.: Gravel used as it comes from the pits. Yost pit considered first-class. Fisher pit considered fair.
New York Central & Hudson River	Fisher	3,262.00	3,246.00	0.50	74.0	23.5	2.5	
Richmond, Fredricksburg & Potomac	Massaponix	2,869.00	2,859.00	0.35	55.0	41.9	3.1	R. F. & P.: The native ballast is about up to the standard of other good pits in different parts of the U. S., but, on account of the heavy passenger business on this road, it is washed and makes a dustless roadbed. The ballast, after washing, shows the following percentages:—Gravel, over $\frac{3}{8}$" 62.7%, $\frac{3}{8}$" to $\frac{1}{8}$" 22.4%; Sand, less than $\frac{1}{8}$" 14.9%.

NOTES.—The whole sample was quartered to exactly ½ cu. ft., which was weighed, then dried and weighed again to ascertain the percentage of moisture. To determine the percentage of gravel, sand and dust, the ballast was sifted with a standard 10-mesh (10 mesh to the inch), then the portion which passed through the 10-mesh sieve was sifted with a standard 50-mesh sieve. The portion which would not pass through the 10-mesh sieve was calculated as gravel, that which remained on the 50-mesh as sand, and that passing through the 50-mesh was calculated as dust. All percentages were calculated on a weight basis.

The diameter of wire in the 10-mesh sieve was 0.023 inch, and the diameter of wire in the 50-mesh sieve used was 0.008 inch.

(C) CONTINUE INVESTIGATION ON GRAVEL BALAST AND RECOMMENDED METHODS OF GRADING DIFFERENT QUALITIES.

Sub-Committee: J. M. Meade, Chairman; F. T. Darrow, S. N. Williams, A. F. Blaess, L. W. Baldwin.

Your Committee has made extensive tests in regard to classification of gravel for ballast in past years. During this year, Mr. Meade, Chairman of the Sub-Committee on this subject, had a very thorough test made, which is presented herewith.

Tests made last year of river gravel gave results that indicated that gravel which was much higher in sand than called for in the Manual for first-class roadbed gave first-class results, and, therefore, the Committee was unwilling to approve the former recommendations, but further investigations this year show that the reason for this discrepancy was largely due to the use of improper screens and different methods of selecting the sample. Your Committee, therefore, wishes to incorporate in the Manual a brief but complete description of the method of making the test of grading gravel for ballast, as follows:

CONCLUSION.

METHOD OF TESTING QUALITY OF GRAVEL FOR BALLAST.

(1) The size of the sample to be tested should be approximately one cubic foot.

(2) Five average samples of about one cubic foot each should be selected from various parts of the pit, which is to be tested. The five samples should then be thoroughly mixed and about one cubic foot of the mixture selected for testing.

(3) To separate the gravel from the sand and dust use a No. ten (10) screen (ten meshes to the inch), made of No. 24 wire (B. & S. gage); to separate the sand from the dust use a No. fifty (50) screen (fifty meshes to the inch), made of No. 31 wire (B. & S. gage).

(4) Measure the percentage of gravel, sand and dust taken from the sample by volume, giving the percentage of each ingredient, compared to the volume of the sum of the ingredients, as follows:

$$\text{Per cent. of sand} = \frac{S}{G + S + D}$$

Where S = Volume of sand.
G = Volume of gravel.
D = Volume of dust.

(5) When sample is shipped for test it should be carefully and securely marked with name and location of the pit from which it was taken.

The above will necessitate canceling the following paragraph on page 47 in the Manual. *"The term percentage above is used to indicate the proportion of the original bulk."*

PER CENT. OF SAND IN GRAVEL.

Examination of Appendix A will indicate a considerable variation of per cent. of sand and dust found in gravel taken from various rivers, although the results obtained from the use of those gravels for ballast is reported as satisfactory from various railroads which use them. The fact that some gravel which is high in sand and dust is reported as giving good results, it is believed, is due to the fact that it is the best material available for ballast in that locality, but your Committee feels that from tests made at ballast washing plants, the percentages given in the Manual for washed gravel will give very satisfactory results.

CLEANING STONE BALLAST.

Appendix B is a copy of report on cleaning stone ballast made by Mr. W. I. Trench, Division Engineer, to Mr. S. A. Jordan, Engineer Maintenance of Way, of the Baltimore & Ohio Railroad, which report was forwarded to the Chairman after the last Ballast Committee meeting and is included as information. The investigation by Division Engineer Trench and Supervisor Zepp has resulted in a very material saving in this class of work.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

Your Committee recommends the following subjects for investigation for the year 1913:

(1) Further investigation of the proper depth of ballast of various kinds to insure uniform distribution of loads on roadway.

(2) Revise the ballast sections, with particular reference to the use of a sub and top ballast.

(3) Investigate methods of cleaning stone ballast and obtain cost of same by various methods.

Respectfully submitted,

COMMITTEE ON BALLAST.

Appendix A.

REPORT OF TEST ON GRAVEL BALLAST.

By H. B. MacFarland,

Engineer of Tests, Atchison, Topeka & Santa Fe Railway System.

The object of this test was to secure comparable figures showing the amount of gravel, sand and dust in the different samples of gravel ballast sent in by the various railroads, as listed below:

Sample No.	Road	Pit	From	By
1	N. Y. C. & H. R.	Fisher	Buffalo, N. Y.	B. M. MacDonald
2	C. B. & Q.	O'Neill	O'Neill, Nebr.	
3	C. B. & Q.	Denver	Denver, Colo.	R. G. Aylsworth
4	C. B. & Q.	Atchison	Atchison, Kans.	E. C. Malbridge
5	I. C.	Glenville	Dubuque, Ia.	C. W. Pifer
6	I. C.	Riverton	Mattoon, Ill.	F. B. Oren
7	C. B. & Q.	Peetz	Sterling, Colo.	G. L. Griggs
8	I. C.	Forreston	Freeport, Ill.	E. J. Boland
9	I. C.	Cherokee	Ft. Dodge, Ia.	H. Gilleas
10	C. R. I. & P.		Benton, Ark.	
11	C. B. & Q.	Ballantine	Lincoln, Nebr.	F. T. Darrow
12	R. F. & P.		Richmond, Va.	S. B. Rice
13	G. R. & I.	Kalamazoo	Grand Rapids, Mich.	F. J. Stimson
14	G. R. & I.	Belmont	Grand Rapids, Mich.	F. J. Stimson
15	A. T. & S. F.	Chillicothe	Chillicothe, Ill.	W. A. Guild
16	N. Y. C. & H. R.	Yosts	Albany, N. Y.	C. E. Lindsay
17	Mo. Pac.	Ft. Gibson	Ft. Gibson, Ok.	H. E. Hale
18	Mo. Pac.	Bethel	Bethel, Ark.	H. E. Hale
19	C. R. I. & P.	St. Louis	Topeka, Kans.	J. M. Brown

On the following pages are shown photographs of the ballast as received.

TESTS.

Samples Nos. 9, 11 and 19 contained considerable foreign matter, such as cinders and weeds.

All the samples were photographed in the same position as to camera and ballast, so as to make the sizes of material comparable on all photographs. The whole sample was then quartered to exactly ½ cubic foot, which was weighed, then dried and weighed again to ascertain the percentage of moisture.

To determine the percentage of gravel, sand and dust, the ballast was sifted with a standard 10-mesh sieve (10 mesh to the inch), then the portion which passed through the 10-mesh sieve was sifted with a standard 50-mesh sieve. The portion which would not pass through the 10-mesh sieve was calculated as gravel, that which remained on the 50-mesh as sand, and that passing through the 50-mesh sieve was calculated as dust. All percentages were calculated on a weight basis.

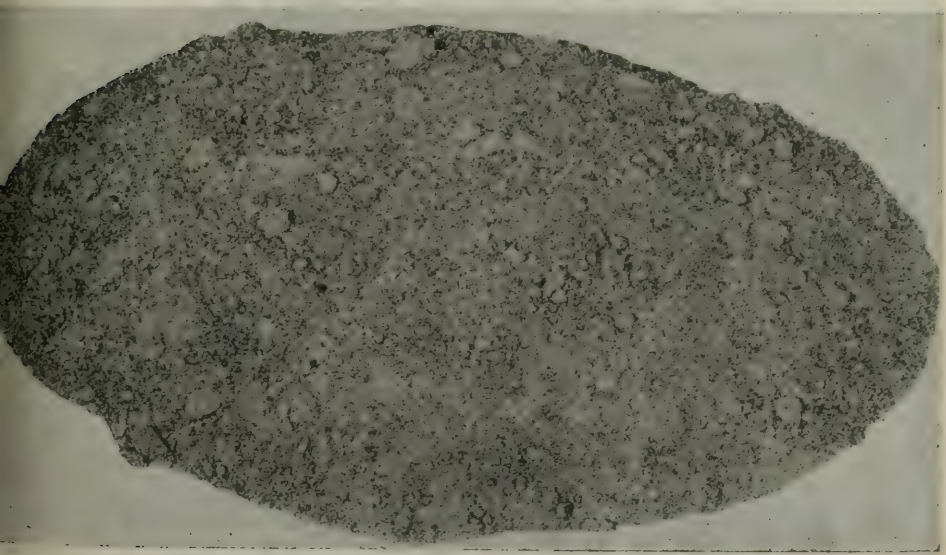
RESULTS OF TEST.

On the following page is shown the percentage of gravel, sand and dust contained in each of these samples as received.

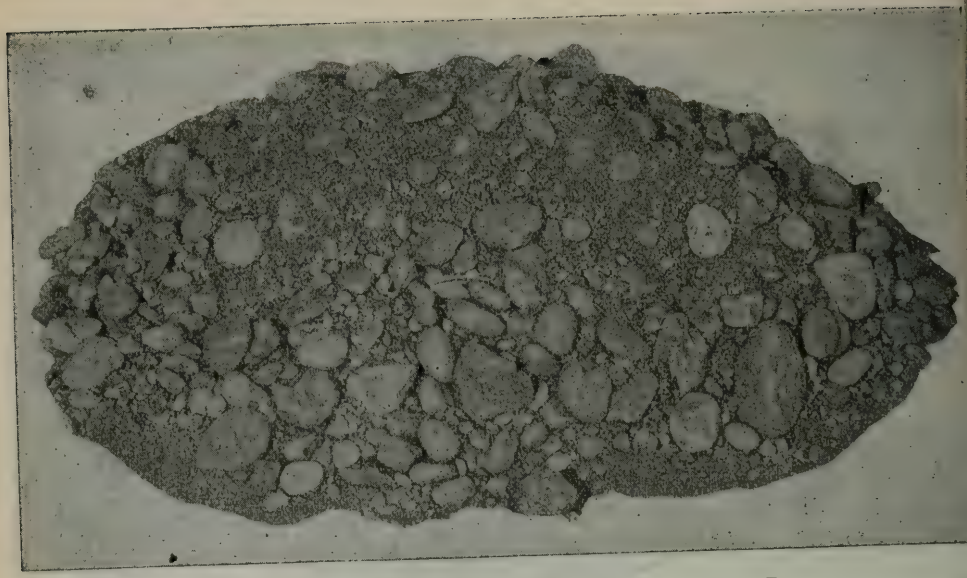
GENERAL DATA.

Sample No.	Railroad	Pit	Weight Per Cu. Yd.		Moisture, Per Cent	Gravel, Per Cent	Sand, Per Cent	Dust, Per Cent
			As Rec'd, Pounds	Dried Pounds				
1	New York Central & Hudson River	Fisher	3,262	3,246	0.50	74	23.5	2.5
2	Chicago, Burlington & Quincy	O'Neil	2,680	2,659	0.75	19	61.8	19.2
3	Chicago, Burlington & Quincy	Denver	3,216	3,197	0.58	67	29.2	3.8
4	Chicago, Burlington & Quincy	Atchison	2,856	2,814	1.47	66	28.7	5.3
5	Illinois Central	Glenville	3,134	3,118	0.50	38	51.3	10.7
6	Illinois Central	Riverton	3,345	3,313	0.95	58	37.8	4.2
7	Chicago, Burlington & Quincy	Peetz	2,878	2,854	0.82	58	38.9	3.1
8	Illinois Central	Forreston	3,181	3,162	0.61	82	13.8	4.2
9	Illinois Central	Cherokee	2,543	2,532	0.44	81	15.8	3.2
10	Chicago, Rock Island & Pacific		3,242	3,214	0.82	63	20.4	16.6
11	Chicago, Burlington & Quincy	Ballantine	3,096	3,068	0.90	59	18.9	22.1
12	Richmond, Fredricksburg & Potomac		2,869	2,859	0.35	55	41.9	3.1
13	Grand Rapids & Indiana	Kalamazoo	3,411	3,403	0.23	77	18 0	5.0
14	Grand Rapids & Indiana	Belmont	3,293	3,279	0.44	64	28.7	7.3
15	Atchison, Topeka & Santa Fe	Chillicothe	2,988	2,975	0.44	54	39.3	6.7
16	New York Central & Hudson River	Yosts	2,856	2,846	0.34	62	33.9	4.1
17	Missouri Pacific	Ft. Gibson	2,682	2,669	0.49	91	6.5	2.5
18	Missouri Pacific	Bethel	3,034	2,935	1.60	76	20.9	3.1
19	Chicago, Rock Island & Pacific	St. Louis	3,041	3,026	0.50	94	5.3	0.7

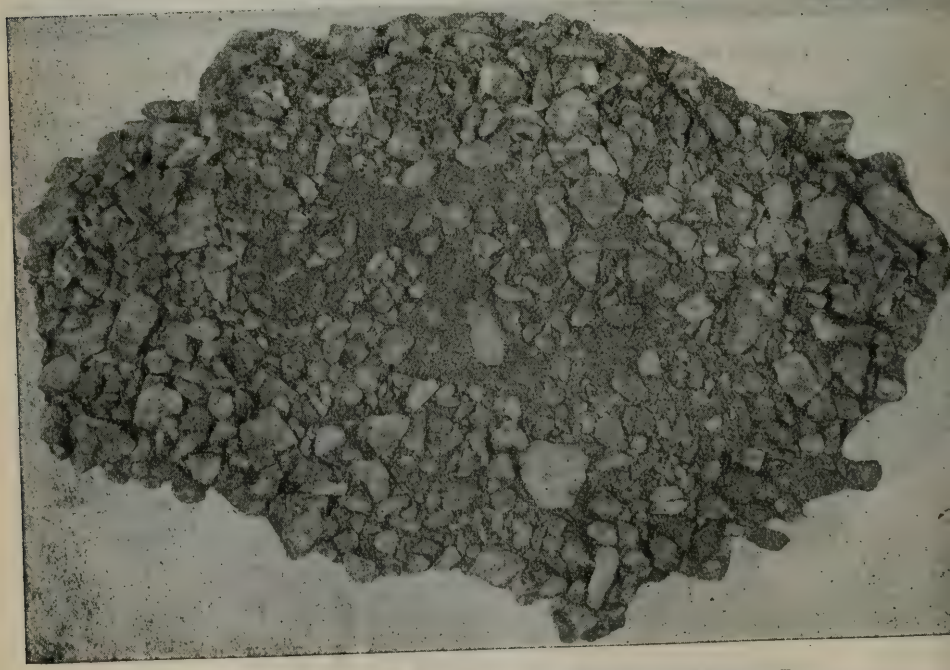
PHOTOGRAPH OF SAMPLE NO. 1—N. Y. C. & H. R., FISHER PIT.



PHOTOGRAPH OF SAMPLE NO. 2—C., B. & Q., O'NEILL PIT.



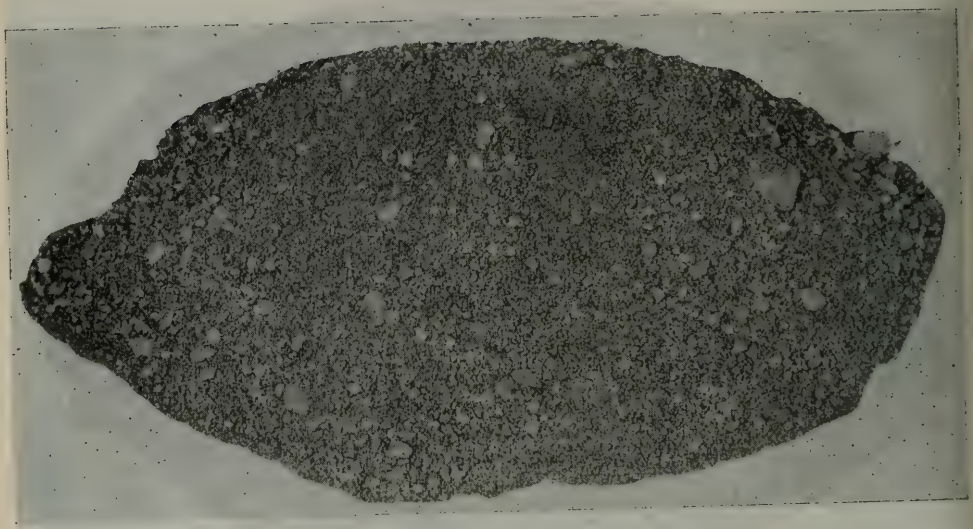
PHOTOGRAPH OF SAMPLE NO. 3—C., B. & Q., DENVER PIT.



PHOTOGRAPH OF SAMPLE NO. 4—C., B. & Q., ATCHISON PIT.

PHOTOGRAPH OF SAMPLE NO. 5—I. C., GLENVILLE PIT.

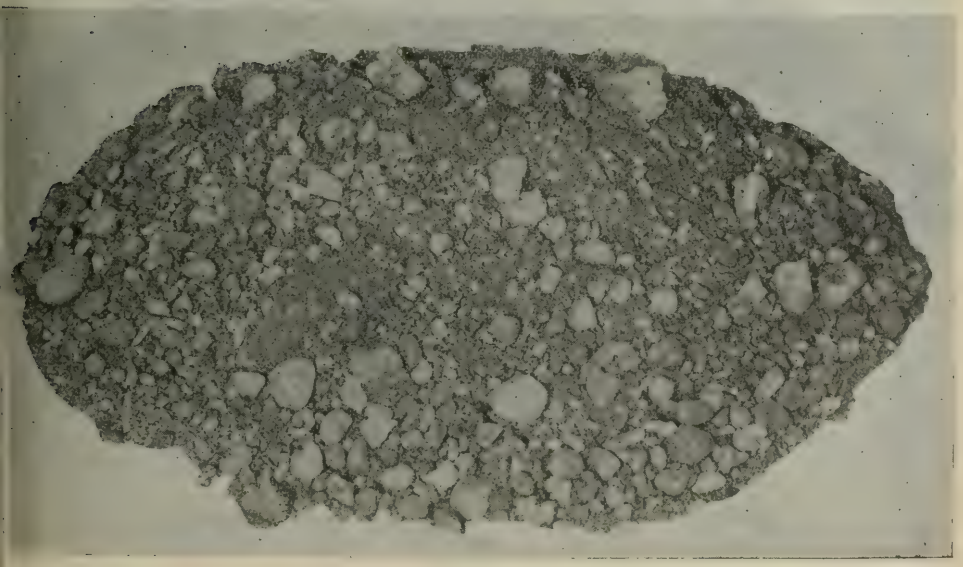
PHOTOGRAPH OF SAMPLE NO. 6—I. C., RIVERTON PIT.



PHOTOGRAPH OF SAMPLE NO. 7—C., B. & Q., PEETZ PIT.

PHOTOGRAPH OF SAMPLE NO. 8—I. C., FORRESTON PIT.

PHOTOGRAPH OF SAMPLE NO. 9—I. C., CHEROKEE PIT.



PHOTOGRAPH OF SAMPLE NO. 10—C. R. I. & P., PIT NOT GIVEN.

PHOTOGRAPH OF SAMPLE NO. 11—C., B. & Q., BALLANTINE PIT.

PHOTOGRAPH OF SAMPLE NO. 12—R. F. & P., PIT NOT GIVEN.

PHOTOGRAPH OF SAMPLE NO. 13—G. R. & I., KALAMAZOO PIT.

PHOTOGRAPH OF SAMPLE NO. 14—G. R. & I., BELMONT PIT..

PHOTOGRAPH OF SAMPLE NO. 15—A., T. & S. F., CHILLICOTHE PIT.

PHOTOGRAPH OF SAMPLE NO. 16—N. Y. C. & H. R., YOSTS PIT.

PHOTOGRAPH OF SAMPLE NO. 17—MO. PAC., FT. GIBSON PIT.

PHOTOGRAPH OF SAMPLE NO. 18—MO. PAC., BETHEL PIT.

PHOTOGRAPH OF SAMPLE NO. 19—C., R. I. & P., ST. LOUIS PIT.

RESULTS.

The results of this test show that the weight of gravel per cubic yard, as received, varied from a minimum of 2,543 lbs. to a maximum of 3,411 lbs., and the material, after being dried, varied from a minimum of 2,532 lbs. to a maximum of 3,403 lbs. The per cent. of moisture varied from a minimum of 0.23 per cent. to a maximum of 1.60 per cent.; the per cent. of gravel varied from a minimum of 19 per cent. to a maximum of 94 per cent.; the sand varied from a minimum of 5.3 per cent. to a maximum of 61.8 per cent., and the dust from a minimum of 0.7 per cent. to a maximum of 22.1 per cent.

Appendix B.

CLEANING STONE BALLAST BY USE OF SCREENS.

By W. I. Trench,
Division Engineer, Baltimore & Ohio Railroad.

During the summer of 1912, experiments were made on the Baltimore & Ohio Railroad with screens in cleaning stone ballast, as opposed to the method of shaking out with ballast forks now generally in vogue on the railroads of this country. A screen shown in use in accompanying photographs and developed by the writer and Supervisor A. G. Zepp, of Baltimore, is the subject of this discussion. In approaching the problem of cleaning ballast by means of screens, it was recognized that the present methods involved one of the most expensive and tedious operations occurring in railway maintenance and that for this reason the periodical cleanings are often deferred much longer than good practice would seem to demand. It was felt that if a screen could be designed which would make a proper separation of stone and dirt and at the same time dispose of these two materials in a way to avoid further handling, with a single cast of the shovel instead of the repeated sifting motion and the further shoveling of the dirt in its disposal as required by the fork, an enormous saving could be made.

It was believed that to be practicable this screen must be as cheap as was commensurate with durability, easily portable, and so related in position to the track when in use as to make its removal unnecessary on the passage of trains. Its operation must be progressive along the track and complete, working toward the dirty ballast and leaving the clean ballast behind it in such shape as to require no further handling. Its capacity must be limited only by the speed with which the laborers can handle the shovel and it must be susceptible to use by a gang, so arranged that the work of every man is continuous and unchanging and so proportioned that no man's work is dependent on the progress made by another; that is, there should be no halts. It is believed that these results have been secured in the screen to be described and that its use, by a properly organized gang, will result in such a saving as to make the further general use of the fork method improbable.

Experiments on the Baltimore & Ohio Railroad were made on a portion of its double track line, and it was found that the most efficient gang for this condition was one of twelve men equipped with three screens. Photograph No. 1 shows such a gang at work. It will be seen from this photograph that there is a screen for each berm and one for the center ditch. The construction of all three is identical, there being interchangeable legs for use on the berm (Fig. 1-A), and in the center ditch. The legs for use on the berm are so designed that the screen rides on the ends of the ties outside the rail at such a distance from the track

as not to interfere with traffic, and at the same time deposits the cleaned stone on the berm in final position. It stands at such an elevation that the dirt is deposited directly into a wheelbarrow standing on subgrade. The legs for use in the center ditch are designed to ride on the cleaned subgrade as the screen is slid along and are of such a height that the dirt is deposited in a handbarrow, which is placed beneath the screen, and the clean stone is left in the center ditch in final position. The upper end of the screen is carried on supports (Fig. 1-B), which are readily adjustable in height to accommodate it for use in the center ditch or on the berm in either cut or fill. When in use in the center ditch, the screen is laid flat upon the ground on the passage of trains, as indicated in Fig. 2-A, and lies wholly below the top of rail.

A short description of the structural details will be made so that a better understanding will be had of the method of operation to follow. The screen frame (Fig. 1-C) is constructed of standard 2-in. x 3-in. x 1¼-in. angle iron set up so that the short leg turns out, the long leg

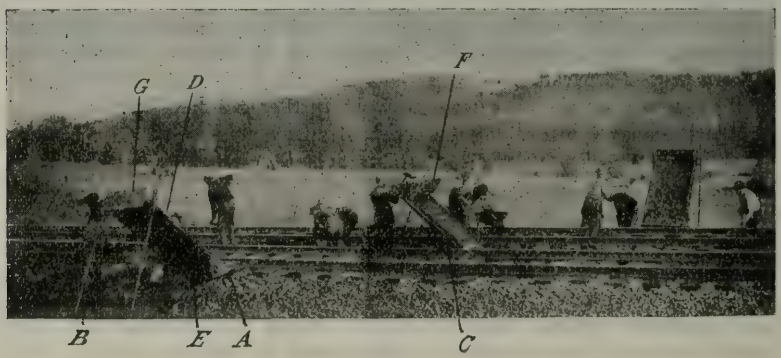


FIG. 1.

forming the vertical sides of the screen. The screen proper (Fig. 2-B), is formed of ¼-in. rods, crimped together, giving a mesh ¾ in. x 8 in. It was found with this mesh and with the screen inclined at 45 degrees that the separation of stone and dirt was perfect even in damp weather, and this cannot always be said of the results secured from forks. These crimped rods are set in a rectangular steel frame (Fig. 2-C) made of 1-in. x ½-in. x ⅛-in. channel iron, and this frame is bolted inside the main frame so that the screen proper can be readily detached, as a whole, and sent to the shop for repairs. The entire screen is backed with a galvanized iron slide (Fig. 1-D), which is so formed that it gathers the dirt which has come through any part of the screen and deposits it in a receptacle set beneath by means of a spout (Fig. 1-E). The spout is really a hinged door suspended at its outer end by a chain and convenient fastening so that its height can be regulated, and when the receptacle is removed for emptying, can be closed. With this door closed

the screen will hold about one wheelbarrow load of dirt, so that the operation of the screen is not stopped while dirt is being dumped. At the top of the screen is a hood (Fig. 1-F) which is used in the position shown when in the center ditch, forming a deflector for the ballast thrown over the top, the method of operation in this case being to slide the screen backwards from the cleaned ballast towards the uncleaned ballast, the latter being thrown over the top and being left in clean condition at the bottom. This hood when screen is in use on the berm is thrown back (Fig. 1-G), and forms the top against which ballast is thrown when in this position. The screen constructed as indicated is practically indestructible and will support the weight of a man without impression.

FIG. 2.

For use with each screen is provided a galvanized iron handbarrow (Fig. 4-A) (Fig. 2-D), which is so formed that it fits exactly upon the horizontal legs when in use on the berm, being so placed after a sufficient quantity of cleaned ballast has been allowed to fall outside the rail, the remainder being caught in the handbarrow and drawn across the rail to be deposited in the cribs. When in use in the center ditch, the handbarrow is placed beneath to catch the dirt.

The cross-section of the finished work is shown in Fig. 5. It will be noted that the cribs are cleaned to the bottom of the ties, the center ditch 18 in. below the top of rail and the berm 24 in. below the top of rail at the end of tie and sloping to 3 ft. below top of rail at back of side ditch. Every 50 ft. one crib is cleaned to the bottom of the center ditch on one end and to the top of subgrade on the other, forming an outlet

for water collected in the center ditch. This arrangement gives an absolutely dry and stable roadbed. The dirt from the ballast, or so much of it as is required, is dressed upon the subgrade outside the ballast line, and in addition to giving a neat black appearance and a pleasing contrast to the white stone ballast, serves to keep down weeds very effectually. What is not required for this purpose is used to widen embankment along the line.

As stated above for double track work, three screens are used. When tracks are on fill on both sides, dirt from each side screen is disposed of on its own side of the embankment, and dirt from the center ditch is dumped directly from handbarrow over bank on side most desirable. When one side is on fill and other side in cut, wheelbarrow loads of dirt are wheeled or carried bodily from cut side to fill side. When it is necessary to carry dirt across tracks, care is used to keep the screen on the

FIG. 3.

side from which it is carried in an advanced position, with reference to the other screens, so that dirt will be carried over uncleaned roadbed and not over that which has been cleaned. This is clearly illustrated in Fig. 1, where the side of track towards the observer is in cut and the other side on fill. It will be seen that dirt carried to the fill on other side of tracks from the center screen passes over dirty ballast before the arrival of the screen to the right, and likewise, dirt from the screen to the left passes over the tracks before the arrival of either of the other two screens, the screens in this case traveling from right to left. When tracks are in cut, on both sides, wheelbarrow loads are wheeled out to end of cut at nearest end, the handbarrow from the screen in the center ditch being dumped into a wheelbarrow or shoveled directly from pan to barrow standing across one rail, as shown in Fig. 4-B, dirt from side screens being poured from screens directly into wheelbarrow. It is

found that dirt can be wheeled out of a cut for a distance of 800 ft. to 1,000 ft. at less expense than would be the case if thrown upon the ground and loaded again upon a work train on a busy railroad.

The following gang organization is adhered to: For the operation of three screens as indicated under ordinary circumstances, twelve men are sufficient; with long hauls of dirt, more men to be added for wheelbarrow work, so screen gang will be kept going. Of the twelve men, two shovel from each side of berm onto their respective screens, two from the center ditch onto the center screen, and one man in center of each track shoveling from the cribs onto the screen most available. One man with pick advances ahead of shovelers to loosen hardened ballast before their arrival. These are dispensed with if ballast is loosened by means of a plow

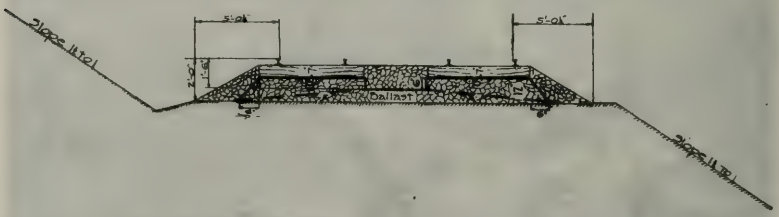
FIG. 4.

attached to work engine. Long stretches of ballast can be loosened in this way in a short time by work engine; enough to keep gang going several days. The remaining three men are sufficient usually to handle wheelbarrows in disposal of dirt, dress dirt down on berm and fork a uniform ballast line, although if hand laid ballast line is required, more men would be necessary. By careful handling of this gang, ballast and dirt are disposed of at one operation in their final position and no further attention is necessary. In most cases it is found that the cleaning of ballast so reduces its volume that additional stone is necessary. In this case the disposition of the stone from the screens is so handled that the berms and center ditch are filled out completely, and any deficiency occurs between the rails where additional stone can be most con-

veniently distributed from Rodger ballast cars without further handling. The gang of twelve men cost per day: Foreman, $2.40; 11 laborers at $1.60, $19.60; total $20.00.

We find that a gang equipped and organized as above will cover 165 ft. of double track per day of 10 hours, making the cost per mile of double track, $640.00. This, of course, includes cleaning ballast, dressing ballast and disposal of dirt complete. Single track work would cost considerably less than half this amount, as there would be no center ditch to contend with. The ballast really handled in this test was considerably more than the cross-section, shown in Fig. 5, would indicate, as before cleaning the ballast was piled above rail in center ditch and rounded high on berm. An average of 227 wheelbarrow loads of dirt were removed per 100 ft. of double track cleaned.

For comparison with the fork method, the identical gang used above was tried with forks and advanced but 72 ft. per day. This also included the dressing complete and disposal of dirt, it being necessary to shovel the



Note.—Line "A" is line to which one crib is taken out every 50 ft. Line "B" is line to which ballast is cleaned.

FIG. 5—ROADBED SECTION FOR CUT AND FILL.

latter in wheel and handbarrows. This shows a cost per mile of double track, $1,466.00.

We see various figures given from time to time on the cost of cleaning ballast per mile. Some of them are very much less than the above, and we can only believe that this is occasioned by the omitting to include the disposal of dirt and dressing road complete, or on account of cleaning to a less depth in track than indicated above or perhaps a less thorough separation of stone and dirt. In many cases, a raise is given track and ballast put under without cleaning. In the above test, no raise was made. For the quality of work done, we do not believe the figures can be much lessened. This shows a saving of 56 per cent. by use of screen over forks.

This screen weighs about 325 lbs., and can be easily propelled along track by the two shovelers at work at the respective screens, and with the material used in them with careful handling and pointing, they should last for years. The trial lot of three made for us with handbarrows complete by a Baltimore firm cost $45.00 each. We believe, if made in quantity and bid on by competitive firms, the cost would be greatly reduced.

REPORT OF COMMITTEE IV—ON RAIL.

W. C. CUSHING, *Chairman;* R. MONTFORT, *Vice-Chairman;*
E. B. ASHBY, J. D. ISAACS,
J. A. ATWOOD, THOS. H. JOHNSON,
A. S. BALDWIN, H. G. KELLEY,
J. B. BERRY, C. A. MORSE,
M. L. BYERS, G. W. KITTREDGE,
CHAS. S. CHURCHILL, JOS. T. RICHARDS,
F. A. DELANO, J. P. SNOW,
P. H. DUDLEY, A. W. THOMPSON,
C. H. EWING, R. TRIMBLE,
L. C. FRITCH, M. H. WICKHORST,
C. W. HUNTINGTON, *Committee.*

To the Members of the American Railway Engineering Association:

Your Committee on Rail submits the following report:

During the year 1912 the following meetings were held:

At New York, on April 10.
At Pittsburgh, on July 24.
At Atlantic City, on September 20.
At Chicago, on November 18.

The membership of the Committee remained the same as for the previous year, with the exception of the addition of Mr. L. C. Fritch.

The work outlined by the Board of Direction for the year was as follows:

(A) Consider revision of the Manual; if no changes are recommended, make statement accordingly.
(B) Present recommendations on standard rail sections.
(C) Continue investigation of rail failures and present conclusions drawn therefrom.
(D) Continue special investigation of rails.
(E) Make concise recommendations for next year's work.

(A) REVISION OF MANUAL.

(a) Revision of Specifications for Carbon Steel Rails:

The work of the Committee resulted, after several years, in the presentation, at the annual convention in 1912, of a set of specifications for carbon steel rails, which was adopted by the Association.

Since that time, some criticisms of the clearness of the meaning of one or two of the sections have been received, and the Committee has made a careful study of all the sections in the specifications, with a view to keep-

ing them up to date and making them as perfect as possible, with the result that a few revisions are now submitted for adoption by the Association, some of them being merely changes in wording and rearrangement, which it is hardly necessary to point out in detail. The principal changes are, however, laid before you for approval, as follows:

Section 4. Chemical Composition:

The words "of each heat" have been added, so that the section reads, "The chemical composition of each heat of the steel from which rails are rolled, determined as prescribed in Section 7, shall be within the following limits."

This change was made because the question arose at one mill as to whether it was necessary for every heat to have its chemical elements within the limits prescribed by the specifications.

Section 14. Elongation or Ductility:

A new paragraph (b) has been added, as follows: "A sufficient number of blows shall be given to determine the complete elongation of the test piece of at least every fifth heat of Bessemer steel, and of one out of every three test pieces of a heat of Open-Hearth steel."

In measuring the elongation, acceptance or rejection is determined by the amount shown under one or more blows of the tup, but in addition to this, it is advisable to determine the total elongation or ductility of a certain number of test pieces, in order to keep informed on the toughness of the material, by repeating the blows till failure results. It is at present customary to carry on these tests, and it was thought advisable and proper to add the requirement to the specifications in order to make them more complete.

Section 17. Bessemer Process Drop Tests, Clause (b):

The words "does not break and" have been added to the second line, so that the clause reads, "If the test piece breaks at the first blow or does not show the required elongation (Section 14), or if the test piece does not break and shows the required elongation, but when broken shows interior defect, all of the top rails from that heat shall be rejected." The words "nicked and" have also been omitted from both Clauses (a) and (b) and both the additions and omissions were brought about by discussion as to the precise meaning of the clause. Some thought that when a test piece showed interior defect the rails it represented should not be rejected unless the test piece had been *nicked* and broken. This was not the real meaning of the clause, as nicking is only a matter of convenience and expedition in making the tests, but in order to avoid controversy, the changes have been made.

Similar changes have been made in (c), (d), (e) and (f).

Section 18. Open-Hearth Process Drop Tests:

Clauses (a) and (b) have been made to read as follows, by the addition of some words and the omission of others:

(a) "If two of these test pieces do not break at the first blow, and if both show the required elongation (Section 14), all of the rails of the heat shall be accepted, provided that none of the three test pieces when broken show interior defect."

(b) "If two of the test pieces break at the first blow, or do not show the required elongation (Section 14), or if any of the three test pieces when broken show interior defect, all of the top rails from that heat shall be rejected."

Before change, these two clauses read as follows:

(a) "If two of these test pieces do not break at the first blow and show the required elongation (Section 14), all of the rails of the heat shall be accepted, provided that these test pieces when nicked and broken do not show interior defect."

(b) "If two of the test pieces break at the first blow, or do not show the required elongation, or if any of the pieces that have been tested under the drop when nicked and broken show interior defect, all of the top rails from that heat shall be rejected."

In Clause (a), the changes were the addition of the words "if both," the addition of the words "none of the three," and the omission of the words "nicked and," also "do not."

In Clause (b), the additions were the words "three tests" and the omission of the words "that have been tested under the drop" and "nicked and."

The changes were made necessary to abolish any cause for dispute as to the meaning, because, as already explained for Section 17 (a) and (b), some were inclined to lay too much stress on the words "nicked and" when considering the rejection of certain rails represented by the test piece which showed interior defect, although it had not been nicked. The nicking was entirely a matter of convenience and if a test piece showed interior defect, it did not make any difference how it was broken. Similar changes have been made in Clauses (c), (d), (e) and (f), for the same reasons.

Section 30. Straightening:

A new clause (b) has been added as follows: "Rails heard to snap or check while being straightened shall be at once rejected."

It is well-known that the present method of straightening rails is undesirable, but it is the one almost universally employed and no other method now known is considered practicable. Sometimes, during this straightening process, rails are heard to snap, indicating that some unusual injury has been done, and it is the object of this clause to make that grounds for rejection.

The attention of the Committee has been called by Dr. Dudley to the automatic rail straighteners in use at the Lorain Steel Works,

which may prove to be of advantage over those now in use, and their merits will be investigated.

Section 32. Finishing:

A new clause (c) has been added, as follows: "When any finished rail shows interior defects at either end or in a drilled hole, the entire rail shall be rejected."

The rejection of such rails at the mills has been a source of dispute for several years, and in order to remove the cause for further contention, this clause has been added. Rejection of such rails is considered justifiable, as in the case of the rejection of the "A," "B" or "C" rails represented by the test piece which shows interior defect.

(b) Revision of Rail Record Forms (Manual, Edition 1911, page 57): "Report of Mill Inspection, Form M. W. 401."

On page 59 of the Manual is shown the present standard form of the Association, entitled "Report of Chemical and Physical Examination," but since the change in the rail specifications, it is no longer suitable for the purpose, because, in the case of Open-Hearth heats, three ingots of each heat are tested instead of one, and an elongation or ductility requirement has been added; consequently, it is necessary to have a form on which the additional results can be reported. The name has been changed to "Report of Mill Inspection," because of the similarity of the form name to that of M. W. 407, "Laboratory Report of Chemical and Physical Examination." A new form, to take the place of the old one, is therefore submitted for your approval.

"Certificate of Inspection, Form M. W. 402."

In connection with the new specifications adopted by the Association, it has become advisable to make changes in the above form, now printed on page 60 of the Manual, and therefore a revised form is submitted to you for your approval. The principal change is the tabulation in two columns of the "Rails Accepted" and the different causes for "Rails Rejected."

"Laboratory Report of Chemical and Physical Examination of Rail, Form M. W. 407."

The present standard form is illustrated on page 67 of the Manual, but, owing to progress in testing, which has resulted in the addition of tests, it has been found advisable to provide for the report of those additional tests; consequently, this form has been entirely revised, and a new blank is presented to you for approval. The old form provided only for chemical analyses and the usual physical tests of tensile strength, elastic limit, elongation and reduction of area, while the new form provides for the report, in addition, of the drop test, hardness test, and transverse test of base.

"Tabulation of Results of Mill Inspection of Rails, Form M. W. 418."

Owing to the change in the rail specifications, it will be necessary to revise this form, which is now illustrated between pages 60 and 61 of the Manual. A new form, with the necessary additions in columns for entering the observed data, is submitted to you for your approval.

(B) STANDARD RAIL SECTIONS.

The American Railway Association delegated to the Rail Committee of the American Railway Engineering Association the question of sections of rail and other matters connected with them, as well as that of specifications.

For some time the subjects of specifications and rail sections have been considered by Sub-Committee "B," Mr. Berry, Chairman, but about a year ago the subject of specifications was delegated to Sub-Committee "A" (in charge of the experimental investigations), while Sub-Committee "B" continued its work in connection with the study of rail sections.

The sections used by the various railroads were collected, comparison between them and sections suggested by members of the Committee was made, and all of the information as to rail failures in connection with the sections which could be obtained was considered. Some of the members of the Committee submitted sections for consideration where their studies suggested that changes might be made for a better section, the desire being to keep the section within certain lines so that rail joints could be used and have a bearing on the straight portion of the rail both under the head and on top of the base, with as little additional stress on the bolts as possible.

At the meeting of the Sub-Committee in Pittsburgh it was decided that while there was some merit in the suggested sections, the Committee is not in a position to recommend any new section at the present time, for the reason that the sections of the so-called A.R.A. types "A" and "B" had been used by a number of roads, and they are getting good results as compared with other sections, but they had only been in use for about three years at the most, and with a great many roads only about two years, so that the Committee is not in a position to suggest any change from those sections at the present time, although it is the consensus of opinion of the Sub-Committee that it may be advisable (but, perhaps, not so much as suggested by the sections under consideration) to add a little to the fillets both under the head and at the base.

The proposal of the Sub-Committee was to continue still to use types "A" and "B" while making further studies in regard to them, and make no recommendation for additional section or sections at the present time.

This was submitted to the whole Rail Committee at Atlantic City in September and it approved of the recommendation of the Sub-Committee.

The Sub-Committee, however, has under consideration modified sections, and will continue the study from time to time as it obtains information concerning the weak spots in the present sections.

It will also undertake to make a study of rail joints and report at future meetings.

In regard to rail stresses: There is a great deal of indefiniteness about how various parties have estimated them. Mr. P. M. La Bach, of the Rock Island Lines, has worked on this problem, and the results have been sent out in sections to the members of the Rail Committee. He is now revising the information, and putting it in better shape. The Committee will also have other data that it will use in connection with the above, and it may be necessary for some members of the Association to make experiments of their own in regard to the matter so that the Committee will have the best information available of what the approximate stresses in rail under normal conditions are.

This is intended to lead up to experiments on the track for the purpose of studying the stresses from measurement under service conditions, if it is found practicable to do so.

The subject of "Stresses to Which Rails are Subjected in Service" has been under preliminary investigation for the past year by Sub-Committee "D," Mr. Baldwin, Chairman. As preliminary information, a short brochure by Dr. P. H. Dudley is submitted as Appendix "M." In this, he describes a few stremmatograph tests of track under service conditions. This is followed by a bibliography of information on the general subject.

(C) STATISTICS OF RAIL FAILURES.

The statistics of rail failures for the year ending Oct. 31, 1911, were prepared by Mr. Trimble, and are given as Appendix "G," having been issued first in Bulletin No. 147, for July, 1912.

The responses have been more complete than ever before, and the information furnished relates to 12,893,007 tons of rail. A careful perusal is recommended, as the report contains a great deal of valuable and useful information; nevertheless, it is proper to call the attention of the members to the fact that it is impossible to make comparisons under similar conditions of traffic, roadbed and weight of rail when dealing with the reports from companies whose problems vary widely, and because it is not feasible to obtain the information which would be necessary to make comparisons accurate, such, for instance, as the tonnage which has passed over rail of equal age and with the same quality of roadbed. The record of comparative wear of special rail, however, is being kept in such a way that comparisons are possible. The deductions from the report will be found on page 372.

(D) SPECIAL INVESTIGATION OF RAILS.

EXPERIMENTS AND TESTS.

Mr. M. H. Wickhorst, Engineer of Tests for the Committee, has continued his work on experiments and tests under the direction of Sub-Committee "A," Mr. Atwood, Chairman, for the past year, and the results of his work are issued in appendices named later. The cost of this work to the railways has been borne entirely by the American Railway Association, and the total appropriations made since November, 1909, up to November, 1912, have been $21,000, while the expenditures to the end of the same period were $21,011.41. These appropriations were divided for each year as follows:

November, 1909	$ 5,000
November, 1910	6,000
October, 1911	10,000
Total	$21,000

In addition to the above, some of the manufacturers have incurred large expenses, the amount of which is not known, through the use of their facilities and material when the investigations were made.

During the year 1912 the Engineer of Tests made reports to the Rail Committee as follows:

No. 22, March, 1912, Abrasion Tests of Rails on Revolving Machine (Bulletin No. 147).

No. 24, April, 1912, Influence of Titanium on Bessemer Ingots and Rails (Bulletin No. 147).

No. 25, May, 1912, Pipeless Ingots (Bulletin No. 147).

No. 26, June, 1912, Transverse Ductility of Base of Rails (Bulletin No. 147).

No. 33, October, 1912, Influence of Silicon on Open-Hearth Ingots and Rails, Appendix L (Bulletin No. 151).

Each report contains a summary of the matter contained in it, but below is given a digest of the main results obtained:

Report 22 gave the results of abrasion tests of rails made at several different mills. The tests were made at the South Chicago works of the Illinois Steel Company on a "revolving machine," consisting of a circular track 20 feet in diameter, on which a heavy beam revolved which could be given additional load by means of springs. Under the conditions of this test open-hearth steel of .74 per cent. carbon abraded more slowly than Bessemer steel of .50 to .54 per cent. carbon, but the tests were not entirely satisfactory and were few in number.

Report 24 gave the results of an investigation made at the works of the Lackawanna Steel Company at Buffalo, to determine the influence of titanium on Bessemer steel ingots and rails. A series of heats was made with treatments varying from nothing to .6 per cent. metallic titanium added in the form of a cold 15 per cent. alloy. According to the results

obtained, the use of amounts of .1 per cent. or more of metallic titanium in the manner mentioned, prevents the "honeycombed" condition of the upper part of the ingot found in plain Bessemer steel, but is also attended with a larger and deeper "pipe." The heavy segregation or concentration of carbon, phosphorus and sulphur found in the interior and upper part of ingots of plain Bessemer steel is largely restrained, but the mild negative segregation found in the interior and lower part of the ingot is not materially altered. The brittle zone found in rail of plain Bessemer steel from the upper part of the ingot, as determined by drop and tensile tests, was avoided, but the properties of the rail from the lower two-thirds of the ingot were not changed. Large internal flaws were found in rail considerably lower down from the top of the ingot in steel treated as mentioned, than in rail made from plain steel. Treatments with .05 per cent. metallic titanium produced the above results only in part, but treatment above .1 per cent. had only little additional influence.

Report 25 dealt with an investigation of two special ingots made by the Standard Steel Works Company at Burnham, Pa., by a process which prevents the formation of a "pipe" in the interior of the ingot. The steel was acid Open-Hearth steel treated with titanium. The ingots were shipped to the Maryland Steel Company at Sparrows Point, Md., where they were tested. The main feature of the casting process was a sand core on top of the iron mold. The ingots were cupped down at the top but contained no interior pipe.

Report 26 gave a description of a method for determining the transverse ductility of the bottom of the base of a rail and the load required to break the flanges of a rail supported near the edges of the flanges. The results were given of a few tests made at Buffalo at the works of the Lackawanna Steel Company, of Bessemer and Open-Hearth rails. The method of making the tests was to support a piece of rail about 2 feet long on two supports placed opposite each other near the edges of the flanges under the middle of the length of the rail. The supports were six inches long and placed one-half inch in from the sides of the flanges. The load was applied in the test machine to the top of the rail at the middle. The method may be considered a means of determining the strength of the flange and of determining the transverse properties of the base of the rail, as regards the transverse ductility of the metal in the base and the presence of structural flaws such as seams.

Report 33 gave the results of an investigation made at the Gary works of the Illinois Steel Company on the influence of silicon on Open-Hearth ingots and rails. A heat was used of about .15 per cent. silicon and a series of higher silicons was obtained in this steel up to above .5 per cent. by means of mold additions of finely crushed ferro-silicon. With about one-fourth per cent. silicon or more the ingots were free from most of the honeycomb present in the upper third of the ingot with the heat amount of silicon, but they also had larger pipes. The higher silicons also had less concentrated segregation of carbon, phosphorus and sulphur. Sili-

con had but little influence on the results in the drop test. When tested in the test machine as a beam, the stiffness and breaking load of the rails increased with increase of silicon, while their ductility was not greatly influenced. In longitudinal tensile tests, the yield point and tensile strength increased somewhat with increase of silicon while the ductility remained about the same. In tests of the flange, the load required to break the flange increased somewhat as the silicon increased, while the transverse ductility of the base remained about the same.

The above work concerning both titanium and silicon indicate that they tend to restrain segregation of carbon, phosphorus and sulphur, but used as they were in this work they were attended with larger pipes. This suggests the idea that in order to obtain the full benefits of their use, a method of casting the ingots is necessary whereby the pipe is avoided or minimized.

MISCELLANEOUS.

Testing Each Ingot:

The question of testing each ingot has been quite thoroughly considered by correspondence and by discussion, and the Committee recommends that no change be made in the specifications in this respect at present, for the following reasons:

(a) The tests now required by the specifications are sufficient to determine the character of the metal in the heat. In so far as it is intended to discover specific flaws in the rail, additional tests would have relatively little value, as these defects are quite local, and are apt to occur in any part of the ingot, or rail bar; so that the presence or absence of internal defects in the piece tested is no certain criterion of the presence or absence of similar defects in other parts of the same bar.

(b) The character of the metal in the rails of one heat varies *down* the ingot more than it does from one ingot to another, and in making the complete drop test of an open-hearth heat, the three tests made from approximately the poorest parts of the ingots designate the average of the poorest part of the metal fully as well as if we tested a piece from each ingot.

(c) Careful examination in detail of the many tests of open-hearth rail made in the last two years on the New York Central Lines fails to show any necessity for the testing of each individual ingot.

Ductility and Elongation Tests, Appendix "A": (Bulletin No. 147.)

Dr. Dudley has written a description, in Appendix "A," of the ductility and elongation tests as conducted on the New York Central Lines, which was intended to be a part of last year's report, in Bulletin No. 143. Such information is interesting and instructive, as we like to keep informed of how our fellow-members handle the daily problems which come before them.

Influence of Seams or Laminations in Base of Rail on Rail Failures, Appendix "F": (Bulletin No. 147.)

Mr. H. B. McFarland, Engineer of Tests of the Santa Fe System, has furnished the Committee with an important study of base failures, which supplements the work of like character presented by Mr. Wickhorst in Appendix "E," entitled "Transverse Ductility of Base of Rails." This type of failure has been dwelt upon at great length by Mr. James E. Howard, Engineer-Physicist of the Bureau of Standards, in the report of accident on the Great Northern Railway, near Sharon, N. D., December 30, 1911. The Committee is making a special study of this character of failure, in order to devise a practicable test which will result in its discovery before the rails leave the mill.

Effect of Piping, Cavities and Porous Spots In Ingots on the Finished Rail, Appendix "H": (Bulletin No. 147.)

Our knowledge on this subject has been improved through the study by Mr. Onderdonk, Engineer of Tests of the Baltimore & Ohio Railroad System. The study is a very important one, as it is impossible to have sound rails from unsound ingots.

Investigation of Silvery Oval Spots, Sometimes Called "Transverse or Internal Fissures," in the Rail Heads, Appendix "I":

The contribution by Mr. C. D. Young, Engineer of Tests, and by Mr. F. N. Pease, Chemist, of the Pennsylvania Railroad, on this subject is a valuable addition to our knowledge, as there has been quite a dispute over the cause of this type of defect, which was but recently brought to our attention. It is quite possible that such defects have heretofore caused rail failures, but if such be true, it has not been a matter of general knowledge.

Method of Producing Sound Ingots, Appendix "J":

This is another appendix relating to sound ingots, which we have been extremely fortunate in securing for the information of our members, as the articles are by a Past-President of the Iron and Steel Institute of Great Britain, Sir Robert A. Hadfield, a manufacturer of steel, and a profound student of the problems arising in its manufacture. This information is an important addition to that of Mr. Wickhorst's report on "Pipeless Ingots," in Appendix "D," as there is some difference in the practice described in the two papers, which Sir Robert has himself explained in a note in the introduction to his reports.

The Testing of Rails, Appendix "L":

This is a foreign paper, taken from the Bulletin of the International Railway Congress, which contains information in line with Mr. Wickhorst's "Abrasion Tests on Revolving Machine," issued as Appendix "B."

(E) RECOMMENDATIONS FOR WORK IN 1913.

The subjects recommended for assignment to the Committee for 1913 are the same as those already assigned for the year 1912, and in addition the subject of rail joints.

The general line of investigation which the Committee has in view for Mr. Wickhorst is submitted below, and embraces a great deal more work than he can cover in any one year, but it is well to keep before us the subjects which are important and will demand our attention.

The main point kept in mind in the work of the last two or three years has been to conduct it so as to bring out if possible information useful in improving rails for the purpose of making them uniformly safe, and it is probable that this must continue to be our guiding principle for some time to come. Investigations intended to improve the wearing properties of rails must, it would seem, be considered as secondary to those which have uniform safety as the prime consideration. It soon developed that the type of rail failure which was uppermost in our attention a few years ago, namely, split and mashed heads, was traceable to the interior condition of the ingot and our work has consisted therefore largely of "ingot" studies. Recently, failures classified as broken rails and broken base, have been brought more to our attention, due largely to last winter's crop of broken rails. It seems that such failures are largely attended or perhaps caused by deep seams in the base of the rail and it is now proposed that the work of the immediate future be directed toward throwing light on the cause of such seams and methods for their prevention.

Among the subjects needing investigation the following may be listed:

Making Ingots:

(1) Influence of height of ingot on segregation and interior cavities, Bessemer and Open-Hearth steel.
(2) Influence of diameter of ingot, Open-Hearth steel.
(3) Influence of the rate of pouring the ingot.
(4) Influence of temperature of liquid steel when poured into molds.
(5) Influence of thickness of mold.

Making Rails:

(6) Influence of temperature of rolling on high carbon Open-Hearth rails.
(7) Causes of seams in base of rails.
(8) Influence of rate of reduction in rolling.
(9) Influence of methods of cooling on cooling beds.
(10) Effect of cold straightening rails.
(11) Influence of length of time in soaking pit on grain size.

Composition:

(12) Influence of titanium on Open-Hearth ingots and rails.
(13) Quantitative influence of carbon on deflection and ductility.
(14) Quantitative influence of phosphorus on deflection and ductility.
(15) Quantitative influence of manganese on deflection and ductility.

Miscellaneous:

(16) Investigate electric steel rails.
(17) Investigate acid Open-Hearth steel rails.
(18) Influence of low temperatures on ductility and other properties of rails.
(19) Influence of heat treatment on the properties of rail steel.

CONCLUSIONS.

The Committee makes the following recommendations for your approval:

(1) That the revision of the specifications for carbon steel rails, presented herewith, be approved for printing in the Manual.

The revisions, together with the explanations, are given in detail in the first part of the report, under "A—Manual, Section (a)."

(2) That Form M. W. 401, "Report of Mill Inspection," as revised and presented herewith, be approved for substitution in the Manual for the present standard form.

The explanation of the proposed revisions is given under "A—Manual, Section (b)."

(3) That Form M. W. 402, "Certificate of Inspection," as revised and presented herewith, be approved for substitution in the Manual for the present standard form.

The explanation of the proposed revisions is given under "A—Manual, Section (b)."

(4) That Form M. W. 407, "Laboratory Rail Report," as presented herewith, be approved for substitution in the Manual for the present standard form.

The explanation of the proposed revisions is given under "A—Manual, Section (b)."

(5) That Form M. W. 418, "Tabulation of Results of Mill Inspection of Rails," as revised and presented herewith, be approved for substitution in the Manual for the present standard form.

The explanation of the proposed revisions is given under "A—Manual, Section (b)."

Respectfully submitted,
COMMITTEE IV, ON RAIL.

SPECIFICATIONS FOR CARBON STEEL RAILS.

1913.

INSPECTION.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the rails have been made in accordance with the terms of the specifications.

Place for Tests.

2. All tests and inspections shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

MATERIAL.

Material.

3. The material shall be steel made by the Bessemer or Open-Hearth process as provided by the contract.

CHEMICAL REQUIREMENTS.

Chemical Composition.

4. The chemical composition of each heat of the steel from which the rails are rolled, determined as prescribed in Section 7, shall be within the following limits:

Elements	Per Cent. for Bessemer Process		Per Cent. for Open-Hearth Process	
	70 lbs. and over, but under 85 lbs.	85 - 100 lbs. inclusive	70 lbs. and over, but under 85 lbs.	85 - 100 lbs. inclusive
Carbon	0.40 to 0.50	0.45 to 0.55	0.53 to 0 66	0.63 to 0.76
Phosphorus, not to exceed	0.10	0.10	0.04	0.04
Manganese	0.80 to 1.10	0.80 to 1.10	0.60 to 0.90	0.60 to 0 90
Silicon, not to exceed	0.20	0 20	0.20	0.20

Average Carbon.

5. It is desired that the percentage of carbon in an entire order of rails shall average as high as the mean percentage between the upper and lower limits specified.

Modification of Carbon for Low Phosphorus.

6. When the material used at any mill is such that the average phosphorus content of the ingot metal used in the Bessemer process is running below 0.08 and in the Open-Hearth process is running below 0.03, and if it seems mutually desirable, the carbon may be increased at the rate of 0.035 for each 0.01 that the phosphorus content of the ingot metal used averages below 0.08 for Bessemer steel, or 0.03 for Open-Hearth steel.

Analyses.

7. In order to ascertain whether the chemical composition is in accordance with the requirements, analyses shall be furnished as follows:

(a) For Bessemer process the manufacturer shall furnish to the inspector, daily, carbon determinations for each heat before the rails are shipped, and two chemical analyses every twenty-four hours representing the average of the elements, carbon, manganese, silicon, phosphorus and sulphur contained in the steel, one for each day and night turn respectively. These analyses shall be made on drillings taken from the ladle test ingot not less than one-eighth inch beneath the surface.

(b) For Open-Hearth process, the makers shall furnish the inspectors with a chemical analysis of the elements, carbon, manganese, silicon, phosphorus and sulphur, for each heat.

(c) On request of the inspector, the manufacturer shall furnish a portion of the test ingot for check analyses.

PHYSICAL REQUIREMENTS.

Physical Qualities.

8. Tests shall be made to determine:

(a) Ductility or toughness as opposed to brittleness.

(b) Soundness.

Method of Testing.

9. The physical qualities shall be determined by the Drop Test.

Drop Testing Machine.

10. The drop testing machine used shall be the standard of the American Railway Engineering Association.

(a) The tup shall weigh 2,000 lbs., and have a striking face with a radius of five inches.

(b) The anvil block shall weigh 20,000 lbs., and be supported on springs.

(c) The supports for the test pieces shall be spaced three feet between centers and shall be a part of, and firmly secured, to the anvil. The bearing surfaces of the supports shall have a radius of five inches.

Pieces for Drop Test.

11. Drop tests shall be made on pieces of rail not less than four feet and not more than six feet long. These test pieces shall be cut from the top end of the top rail of the ingot, and marked on the base or head with gage marks one inch apart for three inches each side of the center of the test piece, for measuring the ductility of the metal.

Temperature of Test Pieces.

12. The temperature of the test pieces shall be between 60 and 100 degrees Fahrenheit.

Height of Drop.

13. The test piece shall, at the option of the inspector, be placed head or base upwards on the supports, and be subjected to impact of the tup falling free from the following heights:

For 70-lb. rail .....16 feet
For 80, 85 and 90-lb. rail.....17 feet
For 100-lb. rail .....18 feet

Elongation or Ductility.

14. (a) Under these impacts the rail under one or more blows shall show at least 6 per cent. elongation for one inch, or 5 per cent. each for two consecutive inches of the six-inch scale, marked as described in Section 11.

(b) A sufficient number of blows shall be given to determine the complete elongation of the test piece of at least every fifth heat of Bessemer steel, and of one out of every three test pieces of a heat of Open-Hearth steel.

Permanent Set.

15. It is desired that the permanent set after one blow under the drop test shall not exceed that in the following table, and a record shall be made of this information.

Rail			Permanent Set, measured by Middle Ordinate in Inches in a Length of 3 Feet	
Section	Weight per Yard	Moment of Inertia	Bessemer Process	O.-H. Process
A.R.A.-A	100	48.94	1.65	1.45
A.R.A.-B	100	41.30	2.05	1.80
A.R.A.-A	90	38.70	1.90	1.65
A.R.A.-B	90	32.30	2.20	2.00
A.R.A.-A	80	28.80	2.85	2.45
A.R.A.-B	80	25.00	3.15	2.85
A.R.A.-A	70	21.05	3.50	3.10
A.R.A.-B	70	18.60	3.85	3.50

Test to Destruction.

16. The test pieces which do not break under the first or subsequent blows shall be nicked and broken, to determine whether the interior metal is sound.

Bessemer Process Drop Tests.

17. One piece shall be tested from each heat of Bessemer steel.

(a) If the test piece does not break at the first blow and shows the required elongation (Section 14), all of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(b) If the test piece breaks at the first blow, or does not show the required elongation (Section 14), or if the test piece does not break and

shows the required elongation, but when broken shows interior defect, all of the top rails from that heat shall be rejected.

(c) A second test shall then be made of a test piece selected by the inspector from the top end of any second rail of the same heat, preferably of the same ingot. If the test piece does not break at the first blow, and shows the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(d) If the test piece breaks at the first blow, or does not show the required elongation (Section 14), or if the test piece does not break and shows the required elongation, but when broken shows interior defect, all of the second rails from that heat shall be rejected.

(e) A third test shall then be made of a test piece selected by the inspector from the top end of any third rail of the same heat, preferably of the same ingot. If the test piece does not break at the first blow and shows the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(f) If the test piece breaks at the first blow, or does not show the required elongation (Section 14), or if the test piece does not break and shows the required elongation, but when broken shows interior defect, all of the remainder of the rails from that heat shall be rejected.

Open-Hearth Process Drop Tests.

18. Test pieces shall be selected from the second, middle and last full ingot of each Open-Hearth heat.

(a) If two of these test pieces do not break at the first blow, and if both show the required elongation (Section 14), all of the rails of the heat shall be accepted, provided that none of the three test pieces when broken show interior defect.

(b) If two of the test pieces break at the first blow, or do not show the required elongation (Section 14), or if any of the three test pieces when broken show interior defect, all of the top rails from that heat shall be rejected.

(c) Second tests shall then be made from three test pieces selected by the inspector from the top end of any second rails of the same heat, preferably of the same ingots. If two of these test pieces do not break at the first blow and if both show the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that none of the three test pieces when broken show interior defect.

(d) If two of these test pieces break at the first blow, or do not show the required elongation (Section 14), or if any of the three test pieces when broken show interior defect, all of the second rails of the heat shall be rejected.

(e) Third tests shall then be made from three test pieces selected by the inspector from the top end of any third rails of the same heat,

preferably of the same ingots. If two of these test pieces do not break at the first blow, and if both show the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that none of the three test pieces when broken show interior defect.

(f) If two of these test pieces break at the first blow, or do not show the required elongation (Section 14), or if any of the three test pieces when broken show interior defect, all of the remainder of the rails from that heat shall be rejected.

No. 1 Rails.

19. No. 1 classification rails shall be free from injurious defects and flaws of all kinds.

No. 2 Rails.

20. (a) Rails, which, by reason of surface imperfections, or for causes mentioned in Section 30 hereof, are not classed as No. 1 rails, will be accepted as No. 2 rails, but No. 2 rails which contain imperfections in such number or of such character as will, in the judgment of the inspector, render them unfit for recognized No. 2 uses, will not be accepted for shipment.

(b) No. 2 rails to the extent of 5 per cent. of the whole order will be received. All rails accepted as No. 2 rails shall have the ends painted white and shall have two prick punch marks on the side of the web near the heat number near the end of the rail, so placed as not to be covered by the splice bars.

DETAILS OF MANUFACTURE.

Quality of Manufacture.

21. The entire process of manufacture shall be in accordance with the best current state of the art.

Bled Ingots.

22. Bled ingots shall not be used.

Discard.

23. There shall be sheared from the end of the bloom, formed from the top of the ingot, sufficient metal to secure sound rails.

Lengths.

24. The standard length of rails shall be 33 feet, at a temperature of 60 degrees Fahrenheit. Ten per cent. of the entire order will be accepted in shorter lengths varying by 1 foot from 32 feet to 25 feet. A variation of one-fourth inch from the specified lengths will be allowed. No. 1 rails less than 33 feet long shall be painted green on both ends.

Shrinkage.

25. The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass, the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws,

for a rail 33 feet in length and of 100 lbs. section, of six and three-fourths inches and one-eighth inch less for each ten lbs. decrease in section.

Cooling.

26. The bars shall not be held for the purpose of reducing their temperature, nor shall any artificial means of cooling them be used after they leave the finishing pass. Rails, while on the cooling beds, shall be protected from snow and water.

Section.

27. The section of rails shall conform as accurately as possible to the template furnished by the Railroad Company. A variation in height of one-sixty-fourth inch less or one-thirty-second inch greater than the specified height, and one-sixteenth inch in width of flange, will be permitted; but no variation shall be allowed in the dimensions affecting the fit of the splice bars.

Weight.

28. The weight of the rails specified in the order shall be maintained as nearly as possible, after complying with the preceding Section. A variation of one-half of 1 per cent. from the calculated weight of section, as applied to an entire order, will be allowed.

Payment.

29. Rails accepted will be paid for according to actual weights.

Straightening.

30. (a) The hot straightening shall be carefully done, so that gagging under the cold presses will be reduced to a minimum. Any rail coming to the straightening presses showing sharp kinks or greater camber than that indicated by a middle ordinate of 4 inches in 33 feet, for A. R. A. type of sections, or 5 inches for A. S. C. E. type of sections, will be at once classed as a No. 2 rail. The distance between the supports of rails in the straightening presses shall not be less than 42 inches. The supports shall have flat surfaces and be out of wind.

(b) Rails heard to snap or check while being straightened shall be at once rejected.

Drilling.

31. Circular holes for joint bolts shall be drilled to conform accurately in every respect to the drawing and dimensions furnished by the Railroad Company.

Finishing.

32. (a) All rails shall be smooth on the heads, straight in line and surface, and without any twists, waves or kinks. They shall be sawed square at the ends, a variation of not more than one-thirty-second inch being allowed; and burrs shall be carefully removed.

(b) Rails improperly drilled or straightened, or from which the burrs have not been removed, shall be rejected, but may be accepted after being properly finished.

(c) When any finished rail shows interior defects at either end or in a drilled hole the entire rail shall be rejected.

Branding.

33. (a) The name of the manufacturer, the weight and type of rail, and the month and year of manufacture shall be rolled in raised letters and figures on the side of the web. The number of the heat and a letter indicating the portion of the ingot from which the rail was made shall be plainly stamped on the web of each rail, where it will not be covered by the splice bars. The top rails shall be lettered "A," and the succeeding ones "B," "C," "D," etc., consecutively; but in case of a top discard of twenty or more per cent., the letter "A" will be omitted. All markings of rails shall be done so effectively that the marks may be read as long as the rails are in service.

(b) Open-Hearth rails shall be branded or stamped "O.-H.," in addition to the other marks.

Separate Classes.

34. All classes of rails shall be kept separate from each other.

Loading.

35. All rails shall be loaded in the presence of the inspector.

Hectograph Ink M.W. 601

AMERICAN RAILWAY ENGINEERING ASSOCIATION

No.....

To be attached to Report No..... Sheet No..... of.....Sheets.

.....Place .....Date

REPORT OF MILL INSPECTION
(CHEMICAL AND PHYSICAL EXAMINATION)

of.....Rails (Open Hearth, Bessemer or Special).....Process.....lbs. per yard.....Section

Manufactured by.....Steel Co., at.....Works

For.....

Order Nos.....Dates of Rolling.....

No. of Passes from Ingot to Rail.....Shrinkage allowance at saws.....inches on 33 ft Rails.

Distance between supports on Straightening Presses.....

Nominal discard from Ingots.....per cent from Top.....per cent from Bottom.

Height of Drop.....feet. Weight of Tup 2000 lbs. Supports 3 ft. center to center.

Size of Ingots.....by.....inches. Nominal Number of Rails per Ingot.....

Temperature of Atmosphere from.....to.....

Heat No.	Ingot No. in heat	No. of Ingots in heat	Mill Analysis							Drop Test			Interior Defects Remarks
			Carbon	Phosphorus	Sulphur	Manganese	Silicon	—		Perm. Set 1st. blow inches	No. of Blows to break	Maximum Elongation in inch	
													Specifications 1
													2
													3
													4
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NOTE:- Requirements of Standard Specifications are to be stated on Line 1.

Instructions

One copy of this report to be forwarded to the Chief Engineer M. of W.

See Certificates of Inspection Nos.....

and Shipping Reports Nos.....

Approved.

.....Inspector

.....Chief Inspector Engineer of Tests.

Hectograph Ink M.N.4681-A.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

No.....

To be attached to Report No..... Sheet No..... of.....Sheets

.....Place..... 0312

REPORT OF MILL INSPECTION
(CHEMICAL AND PHYSICAL EXAMINATION)

Heat No.	Ingot No. in heat	No. of Ingots in heat	Mill Analysis							Drop Test			Interior Defects Remarks
			Carbon	Phosphorus	Sulphur	Manganese	Silicon			Perm. Set 1st blow inches	No. of blows to break	Maximum Elongation in inch	
													Specifications 1
													2
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NOTE:- Requirements of Standard Specifications are to be stated on Line 1.

Instructions

One copy of this report to be forwarded to the Chief Engineer M. of W.

See Certificates of Inspection Nos.....

and Shipping Reports Nos.....

Approved.

.....Inspector

.....Chief Inspector Engineer of Tests

Hektograph Ink

M.W. 402

AMERICAN RAILWAY ENGINEERING ASSOCIATION

CERTIFICATE OF INSPECTION

No.....

of ..... (Open Hearth, Bessemer or Special) Process Rails..... lbs. per yard..... Section.

Manufactured by..... Steel Co. at..... Works.

for.....

Mr. ..... Chief Engr. M. of W. Date..... 19.....

The following Steel Rails have been inspected and accepted according to contract.

Rails are certified to be within the limits of the specifications of the.....

.....

and approved as per details given below.—

All Rails have been inspected and approved in accordance with the specifications now in effect.

Dates of Rolling.....

No. of Rails rolled..... No. of Heats rolled..... No. of Heats rejected.....

RAILS ACCEPTED		RAILS REJECTED ACCOUNT OF	
1. As No. 1. (This Rolling)		7. Test (b) Top Rails test piece (or pieces) breaking.	
2. " " 2. " "		8. " " " " " " "	Failing in ductility
3. " " 2. For exceds. specif. defl. " "		9. " " " " " " "	Showing interior defect
4. " " 1. From Stock (See Cert. No.)		10. " (d) Second " " " "	breaking
5. " " 2. " " (" " ")		11. " " " " " " "	Failing in ductility
6. Total Accepted and Shipped.		12. " " " " " " "	Showing interior defect
		13. " (f) Third " " " "	breaking
		14. " " " " " " "	Failing in ductility
		15. " " " " " " "	Showing interior defect
		16. Surface imperfections	
		17. Total Rejected	

Number of Rails of each length

Length		33'	30'		27½'		25'		Total
No. 1.									
No. 2.									

Calculated Weights			Shipper's Scale Weights		
Total Pounds	Tons	Pounds	Total Pounds	Tons	Pounds
No. 1					
No. 2					

R. R. order No.	Amount		Accepted under this Certificate				Balance Due			
			No. 1		No. 2		No. 1		No. 2	
	Tons No. 1	No. 2	Tons	lbs.	Tons	lbs.	Tons	lbs.	Tons	lbs.

See Shipping Reports Nos.....

.....

See Chemical and Physical Reports Nos.....

Trial Weights

Hour	Weights	Hour	Weights
6 A.		6. P.	
7 "		7. "	
8 "		8. "	
9 "		9. "	
10 "		10. "	
11 "		11. "	
12 "		12. "	
1. P.		1. A.	
2. "		2. "	
3. "		3. "	
4. "		4. "	
5. "		5. "	

Instructions

One copy of this Certificate is to be made out and forwarded to the Chief Engr. M. of W., and one copy to the General Superintendent.

Correct .....
Inspector

Approved .....
Chief Inspector
Engr. of Tests

(Front of Form.)

M.W. 407

AMERICAN RAILWAY ENGINEERING ASSOCIATION

No. ..... LABORATORY RAIL REPORT

..... Date ..... 19.....

The following is report on rail referred to in .....

and which FAILED at ..... Place of Failure ..... on ..... Date of Failure .....

Rail made by ..... Manufacturers Name ..... Date ..... Heat ..... Ingot Location .....

CHEMICAL ANALYSIS

Location	C.	P.	S.	Mn.	Si		
A.							
B.							

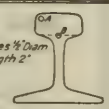
DROP TEST

2000 lb Tup Supports 3' C to C.

Position Head up or down	Height of Drop	Temperature of Atmosphere	Perm. set 1st Blow	No. Blows to break	Max Elong. in 1 inch	Max Elong. in 2 Cons. Ins.	Interior Defects and Remarks
Up							
Down	1' & Up						

TENSILE TESTS

Location of Sample	Yield Point lbs. per sq. inch	Tensile Strength lbs per sq. inch	Elongation per cent in 2 ins	Reduction of Area per cent	Fracture
A					
B					



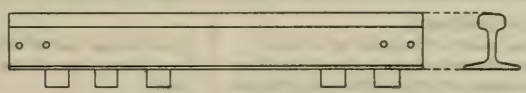
Test Pieces ½" Diam.
Gauge Length 2"

HARDNESS TESTS

Location	1.	2.	3.	4.	5.	6.	7.	8.	Average
Brinell									
Scleroscope									

TRANSVERSE TEST OF BASE

Location	Breaking Load	Distance of Break from Ctr.	Max Elong in 1 inch	Per Set of Specimens Tested on Mid. Ord.	Distance "A"
E. or N. of Fracture					
W. or S. of Fracture					



Show location and character of original fracture.

Remarks .....

.....

.....

.....

.....

.....

Signature

(Back of Form.)

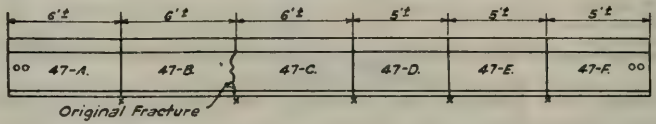
No.....

M.P. 407

AMERICAN RAILWAY ENGINEERING ASSOCIATION

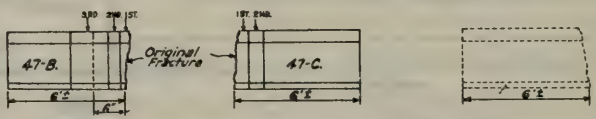
GENERAL INSTRUCTIONS FOR SAMPLING AND TESTING RAILS FOR LABORATORY INVESTIGATION.

Send in to Railroad Test Department, at least two six foot sections, if possible, each to have original fracture intact. Preferably the whole rail is desired to be cut into pieces about six feet long.
Paint identification number and letters on all pieces, about as follows



Rail may be nicked at points shown by "X" and broken in manner usually employed by section gangs.

Before Drop Testing, cut pieces containing original fracture as follows.



Dotted Sections to govern when fracture is near the end.

1ST. CUT ON B. AND C.
Cut off original fracture, no further back than required to give full section in cut.
} To be tagged with identification number and history, photographed and preserved.

2ND. CUT ON B. AND C.
Sections exactly 1" long, one to be highly polished on side nearest original fracture. Take drillings with ½" drill from end of either B. or C. nearest original fracture. If more drillings are needed, take from corresponding part of 3rd. cut
} Scleroscope and Brinnell Tests on one piece, transverse test on both. Compression test on one in order named f.r chemical analysis.

3RD. CUT (Either B. or C., take nearest to original fracture) One Section 4¾" long.
} For tensile tests.

All sections and test specimens to be stamped with identification numbers in shop.

Drop tests to be made as follows:- First test at specified height with base down, second test at one foot increments, starting at one foot with head down. Additional drop tests to be made if desired.

FORM M. W. 418.

TABULATION OF RESULTS OF MILL.
INSPECTION OF RAILS ROLLED.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

THE PLANT OF RESULTS OF MILL INSPECTION OF RAILS ROLLED FROM ... TO ...

| Report Number | Heat Number | Name of Company and Mill where Rolled | Rail: Weight | Rail: Section | Rail: No. of Pieces | No. of Tons Accepted of each Class Rolled: No. 1 Tons | No. 1 Heat Tons | No. 2 Tons | No. 2 Heat Tons | No. of Tons Rejected | No. of Rails Accepted and Class Rolled: No. 1 Rails | No. 1 Tons | No. 2 Rails | No. 2 Tons | No. of Rails Rejected | Number of Rails rejected on account of: a (Top Rails) test piece inclusive: Piping | Breaking | Transverse Fissure | Defective Head | Split Web | Split Head | Bolt Hole Crack | Bad Surface | Bent | Dimensions | Collapsed | Defective Base | Miscellaneous | b (Second Rails) test piece inclusive: Piping | Breaking | Transverse Fissure | Defective Head | Split Web | Split Head | Bolt Hole Crack | Bad Surface | Bent | Dimensions | Collapsed | Defective Base | Miscellaneous | c (Third Rails) not inspected: Piping | Breaking | Transverse Fissure | Defective Head | Split Web | Split Head | Bolt Hole Crack | Bad Surface | Bent | Dimensions | Collapsed | Defective Base | Miscellaneous | Scrapped Ends | Total Rejected | Cause of Failure: Name of Co. | Drop Test: Blows to Break | Height of Fall | Deflection | Static Test: Load | Deflection | Tensile Test: Elastic Limit | Ultimate Strength | Elongation in 8 Inches | Reduction of Area | Nick and Bend Test: Character of Fracture | Bend | Remarks |
|---|---|---

Appendix A.

DUCTILITY AND ELONGATION TESTS.

By Dr. P. H. Dudley.

(Appendix to Report of Committee on Rail in Bulletin 143, January, 1912.)

To the Members of the American Railway Engineering Association:

The following report from Dr. P. H. Dudley was presented to the Rail Committee at its meeting in New York, February 13, 1912:

I have delayed answering your letter in reference to the ductility tests under our specifications until we had more experience in reference to the non-failure of the open-hearth rails which I designed of large ductility and toughness for the low temperatures of our winter service. See section 1, Chemical Composition, and section 4, Drop and Ductility Tests, of attached specifications.

The temperatures in the Mohawk Valley on the New York Central have been 20 degrees below zero for several successive days and 40 degrees below for two or three days. Nearly similar temperatures have been experienced on the Lake Shore & Michigan Southern, and 20 degrees below on the Cleveland, Cincinnati, Chicago & St. Louis Railway. To date, however, out of our 124,000 tons of basic open-hearth rails, commencing with 3,000 tons laid in 1908, 4,000 tons in 1909, which were made under our former specifications of the elongation measurements for single blow of the drop, and including the first rails rolled under our present specification, 10,900 tons in 1910 and 106,000 tons in 1911 under the ductility tests, five 1908 rails failed, though none were reported as broken, five rails have broken in the 1909 rails, which were accepted under the elongation of only a single blow of the drop. It was the latter experience which induced me to provide more complete ductility tests for our basic open-hearth rails, resulting in the present specifications.

To date there has been reported out of 117,000 tons of basic open-hearth steel for 1910 and 1911, five broken rails due to ordinary traffic and four due to bad wheels. This statement is important in consideration of the minimum ductility permissible in our specifications for a few melts of steel.

It is reported by the Engineers of Maintenance of Way that Bessemer rails in the track either side of open-hearth rails were injured by bad wheels without producing any fractures in the latter under the same wheel loads, rates of speed and in the low temperatures mentioned.

I am presenting condensed sheets of ductility tests, with the chemical composition, permanent set, maximum ductility of the metal per inch, the amount of ductility obtained in six inches for a single blow, and the final elongation in six inches—for the ductility of one test butt from each melt was completely exhausted by two or more blows of the drop.

The condensed sheets, Nos. 1 and 2, show, starting with the 100-lb. basic open-hearth rails, Lackawanna, 1910 and 1911, 20 ft. drop, that when

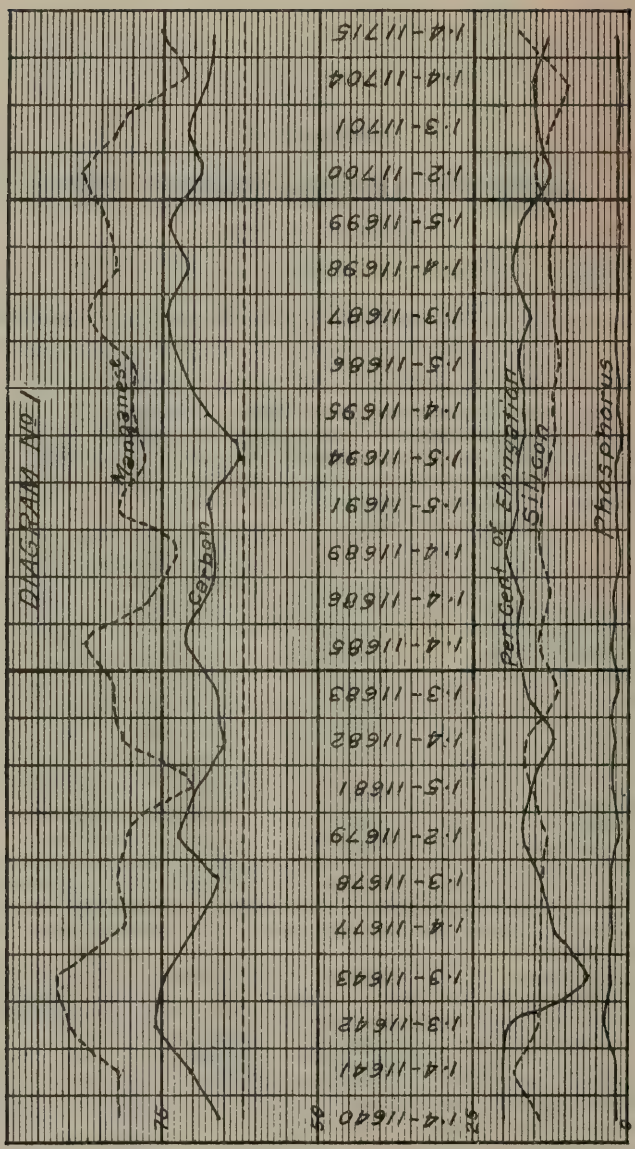
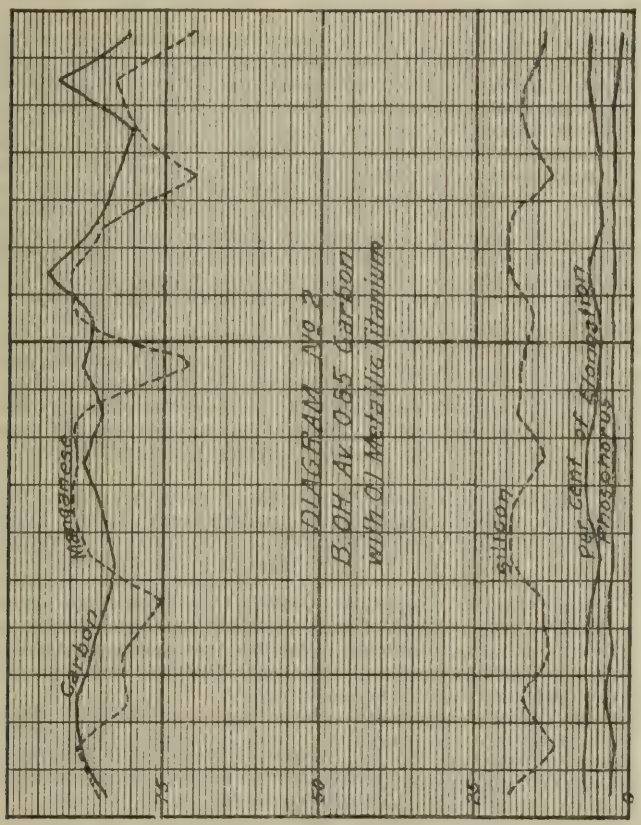


Diagram No. 1
Manganese
Carbon
Per cent of Phosphorus
Silicon
Phosphorus
1.4-11715
1.4-11704
1.3-11701
1.2-11700
1.5-11699
1.4-11698
1.3-11687
1.5-11686
1.4-11695
1.5-11694
1.5-11691
1.4-11689
1.4-11686
1.4-11685
1.3-11683
1.4-11682
1.5-11681
1.2-11679
1.3-11678
1.4-11677
1.9-11643
1.3-11642
1.4-11641
1.4-11640

the manufacturers first commenced to make the steel they were not able to secure a ductility much beyond the minimum stated in our specifications for a few melts and they did not believe it possible to make them very uniform. They were not familiar with the actual ductility in rail steel when its acceptance was confined to the information given only by the elongation per inch for a single blow of the drop.

It will be noted on sheet No. 1 that there were only two melts of 6 per cent. ductility, six melts 7 per cent. and one melt of 8 per cent., the maximum ductility being 20 per cent. in four melts. Sheet No. 2, the



third day of manufacture, there are only two melts as low as 8 per cent., while the general average is over 15 per cent. in 401 melts of steel for 23,000 tons of rails shipped.

It should be stated as general information that the first 10,000 tons were rolled at the Lackawanna plant with the understanding at the mill that their former drop test of 18 ft. should be included as a basis of comparison.

Ductility blank No. 1 shows in detail the tests from Melt No. 1881. The top crop of the 36th ingot was chilled by water in entering the rolls.

It is interesting to note the required retest gave 11 per cent. ductility and the duplicate from the same bar 15 per cent. There is also a comparison of the top of the "C" rail and the bottom of the "C" rail; the top "sheared" at 6 per cent. ductility while the bottom gave 18 per cent., an unusual condition.

Ductility blank No. 2, Melt No. 5228, shows similar tests were made which were more uniform and also that in several instances the top of the "C" rail gave a slightly increased ductility over the bottom of the "C" rail. This corresponds to some of Mr. Wickhorst's tests. Details of the size of the ingots, etc., are given on the ductility blanks Nos. 1 to 7, from the different melts.

Melts 1881 and 5228 are basic open hearth melts of steel to which five-tenths of 1 per cent. of Metallic Titanium was added in the ladle. Condensed sheet No. 3, 80-lb. basic open hearth rails, Lackawanna, 18 ft. drop. The chemical composition for the 80-lb. rails is intended to give increased ductility over the 100-lb. for the reason that in many places it carries the same class of engines and is subjected to heavy traffic in temperatures of 30 degrees to 50 degrees below zero. It will be noted that the ductility of every melt is more than double and some treble the minimum requirements of the specifications; nearly the full value of the chemical composition was obtained, the average ductility for 20,500 tons of rails shipped being 20 per cent. This illustrates the value of the complete exhausted ductility tests, for it is possible in any particular melt which is low in the ductility to trace the specific conditions of the furnace, the melting, scrap used, etc., and bring the next melt up to a more complete purification of the bath. This deals directly with the manufacture of the steel and gives information to the mill people never before accessible and assists them in producing a more uniform quality in the different melts.

The ductility which is possible for a given chemical composition, size of ingots and other steps of manufacture has been practically ascertained. It is easy to see by the exhausted ductility tests whether or not it is secured.

The lower carbon content of the specifications gives one range and the maximum content a higher range and the mean carbon content one between the two. Either one of the three can be used as necessary in locations for safety according to the low temperatures, speeds and wheel loads of service.

The term "ductility" in these specifications is used in a sense of tenacity and toughness of the steel, the exhausted ductility being its measure. This also becomes the soundness test for seams, segregations, slag inclusions or other foreign matter in the web or head of the rails, similar to the special nick test of other specifications.

The elongation and ductility tests of steel rails are made concurrently with their manufacture at the plants under the drop testing machine from four-foot lengths of the top crop of the rail bars, the results being tabulated as shown by the included blanks for Ductility and Elongation Tests, a copy being furnished to the manufacturers.

The butts are tested within three hours or less after the ingots of a melt are teemed and the facts as to the full ductility of the steel as made and rolled are available for the manufacture of subsequent melts. The utilization of such knowledge for each melt has enabled the manufacturers to make rails of greater uniform ductility, homogeneity, safety and economy of the output than was believed possible before such tests were installed, as illustrated by the results shown on the different sheets and dates of manufacture and the non-breakage of such rails is confirmed by experience in the track to date.

Sheets 4 and 5 show tests made during the manufacture of 4,000 tons of Lake Shore & Michigan Southern basic open-hearth rails at the Bethlehem plant. Rejections of two melts are shown on sheet 4, while the

decided improvement in the subsequent ductility obtained is evident on sheet 5.

Sheet 6 shows the condensed ductility tests when commencing to roll 100-lb. Lake Shore & Michigan Southern rails at Gary. Four melts the ductility was 6 per cent., two melts 7 per cent., one 8 per cent., and one 9 per cent., while sheet 7 shows the improvement made in the later rollings at the same plant.

Sheets 8, 9 and 10 show the ductility secured in basic open-hearth rails, of 90, 85 and 80-lb. A.S.C.E. sections rolled at Gary, which are good so far as the steel is concerned and will be of increased service in the track.

The distribution of the metal while balanced as to weight between the head and thin broad base of the A.S.C.E. sections is unbalanced for rolling, and owing to the more rapid absorption of the heat units in the base than in the head more camber is required on the "hot beds" than in the recent narrower and thicker base sections of equal percentages of metal.

It has been shown by extensive Stremmatograph Tests that the spans of the bending rails as girders are controlled by the wheel load contacts and their spacing in the wheel base of the locomotives and cars rather than the cross-tie spacing, consequently the time of the alternate reversal of stresses in the bending rails will be determined by one-half of the length of span and speed of trains, while approximately the magnitude of the stress will depend upon the length of span, equalized wheel load and speed for the same section.

A train at thirty miles per hour runs 44 ft. or 528 in. per second, at sixty miles per hour 88 ft. or 1,056 in. per second, and at ninety miles per hour 132 ft. or 1,584 in. per second. A reversal of the stress of tension in the base of the rail for its positive bending moment under the wheel contacts and the reversal of the strains in the negative bending moment of the wheel spacing will take place while the wheels are running one-half of the distance of their wheel spacing. The strains in the rail section for the same wheel load and wheel spacing would reverse in one-half of the time for sixty miles per hour that was required for thirty miles and for ninety miles in one-third of the time. The conditions of increased speed with the stress of the load shorten the time factor of the metal and section to distribute the passing wheel effects. Increasing the wheel loads also augments the rate of distribution of the strains and the combination may exceed the capacity of the section and tenacity of the metal to distribute the wheel loads without injury. It is obvious that metal of 0.10 phosphorus the rail may be so sensitive to rapid strains that it will not carry the reversal of the same load at sixty miles per hour that it would at thirty miles, as such steel is not able to resist shocks of impact loads though showing 10 to 15 per cent. ductility under static loads in the testing machine.

It is further found that in many locations the greatest breakage of rails on descending gradients is where the speed of the present trains approximate eighty to ninety miles per hour. Rails of the same make on the opposite track in ascending gradients where the same equipment runs over them at the slower speeds have not broken during the late extreme cold weather. This indicates that it is important to study the time factor of any steel to distribute stress under high speed trains in low temperatures. It has been shown by the recent comparisons already mentioned that the open hearth steel has a greater tenacity and toughness to resist the wheel effects of high speed trains than Bessemer rail of 0.10 phosphorus in the same tracks for the same wheel loads and speeds. This fact has already been observed on other lines by Mr. Cushing in his comparison of breakages of Bessemer and basic open-hearth rails. It is possible from the known ductility which may be obtained from a definite chemical composition and proper purification of the bath of metal, to consider a time factor which may be secured for the distribution of strains and provision

thus made for high-speed passenger trains or for a greater abrasive resistance with a lesser ductility for the low-speed heavy freight trains.

This lesser ductility does not alone mean a mere increase of hardness, but an exchange of part of the ductility for increased tenacity and toughness of the metal with an ample time factor for the section to distribute the slower reversal of stresses of the heavy wheel loads of freight service.

The low phosphorus (0.06), with 0.60 to 0.65 carbon, Bessemer rails which I made commencing in 1891, 90 per cent. of those heats were required to sustain a weight of 2,000 lbs. falling 20 ft., which was equivalent in the 100-lb. section to 5 per cent. elongation per inch. The heats of the remaining 10 per cent. which gave 4 per cent. elongation before fracture under the drop, were accepted. The service of those rails in the track with their limited number of breakages and failures shows that for the development of the present high speed trains and wheel loads that the ductility was ample. To give additional security for the present service and wheel loads and particularly in the more frequent recurrence of low temperatures the minimum ductility has been practically raised to 6 per cent. per inch and the complete exhausted ductility reports show the entire average of all the heats has been raised to nearly the full value which can be obtained from a definite chemical composition.

The specifications for passenger service of the different weights of rails for the New York Central lines are of moderate carbon to provide the requisite tenacity and toughness required for low temperatures and the rails are subjected to more severe tests than previously required.

The system of plotting the exhausted ductility per melt for each individual furnace is shown in diagram No. 1. This furnishes the manufacturers a possible standard measure of ductility for the chemical composition and the comparison for each furnace.

The plotting is shown in diagram No. 2 of 0.80 to 0.90 carbon basic open-hearth steel, with one-tenth of one per cent. of metallic titanium added to insure the necessary toughness for the lesser ductility of 6 to 8 per cent. for slow moving heavy trains.

The percentage of the minimum elongation in the specifications for basic open-hearth steel of the 1910 and 1911 rails has not been changed for those of 1912, as the tabulated tests show that the mills after a short experience were able to hold the ductility practically to that which could be obtained from the chemical composition of the specifications.

Yours very truly,

P. H. Dudley.

SPECIFICATIONS FOR BASIC OPEN-HEARTH RAILS.

NEW YORK CENTRAL LINES.

1. Chemical Composition.

	80-lb.	90-lb.	100-lb.
Carbon	.55 to .68	.60 to .73	.62 to .75
Manganese	.70 to 1.00	.70 to 1.00	.70 to 1.00
Silicon	.10 to .20	.10 to .20	.10 to .20
Phosphorus not to exceed	.04	.04	.04

To adjust the chemical composition to the special conditions of manufacture at each mill the engineer representing the railroad company, from the inspection of the ingots, their heating, blooming and rolling into rails, shall have the right to select the lower or average limit of either the silicon or manganese, or both, with the average carbon content as the working basis for making the steel, as he may find requisite for good setting ingots with freedom from pipes and rolling into tough steel by the plant of the manufacturer.

4. Drop and Ductility Tests.

A drop test to be made of a crop from the top bar of the second, the middle, and the last full ingot of the melt. The crop 4 to 6 ft. long to be stamped with a spacing bar of six one-inch spaces on the base, head or side as desired.

Each butt must show under the drop of 18-ft. for the 80-lb. or 90-lb. section and 20-ft. for the 100-lb. section, at least 6 per cent. elongation for one inch or 5 per cent. each for two consecutive inches before fracture for acceptance of the melt.

The crop or butt is liable to be chilled accidentally in entering the rolls several times, or it may be caused by other delays, and should it break under a single blow without showing the percentage of elongation specified, it shall be considered as indicating deficient ductility or chilled metal, and the results must be rejected.

The inspecting engineer representing the railroad company must then take a duplicate test from the same ingot at the top end of the "A" or "B" rail, according to the nine or greater percentage of discard and the results taken in lieu of those from the first crop or test to determine whether or not the piece had the requisite ductility in accordance with the specifications.

The distinction between a chilled crop and those of inadequate ductility must be ascertained according to above prescribed tests before rejections are made or rails accepted.

Should any test piece under the first blow of the drop not break but fail to show the percentage of elongation specified, the test piece shall be subjected in the same position to a second blow and the results so obtained govern in passing the test.

The ductility of at least one specimen of each melt to be exhausted by one or more blows of the drop, and a record made of the respective elongations of each test.

The drop testing machine shall have a tup of 2,000 lbs. weight, the striking face of which shall have a radius of not more than five (5) in. and solid supports, centers three (3) ft. apart, for the test butts. The anvil block shall weigh at least 20,000 lbs. and the supports shall be part of or firmly secured to the anvil. The report of drop test shall state the atmospheric temperature at the time the test was made. The testing shall proceed concurrently with the operation of the mill. The temperature of the test butts, to be between 40 deg. and 100 deg. Farhenheit.

CONDENSED SHEET NO. 1.

100-lb. N. Y. C. Basic Open-Hearth Rails, Lackawanna, 1910 and 1911, 20-ft. Drop.

	Chemical Composition.						Elongation.			
Melt No.	C.	Mn.	Sil.	Phos.	Sul.	Per Set.	Max. Per In.	Total 6 In. Single Blow.	Total Exhausted for 6 In.	Date.
5202.....	.628	.88	.156	.021	.036	1.5	.16	.31	.77	12-12-10
5203.....	.648	.78	.135	.032	.048	1.4	.07	.33	.36	"
12345.....	.672	.91	.123	.017	.036	1.4	.07	.32	.32	"
4920.....	.678	.97	.163	.018	.038	1.4	.07	.29	.33	"
8783.....	.670	.89	.165	.017	.034	1.4	.20	.36	.84	"
5201.....	.710	.90	.160	.019	.039	1.4	.07	.30	.34	"
11641.....	.706	.82	.182	.017	.034	1.4	.20	.31	.85	"
11642.....	.764	.90	.141	.038	.050	1.3	.19	.27	.82	"
8784.....	.664	.87	.139	.028	.037	1.4	.14	.32	.49	"
8782.....	.750	.88	.168	.018	.043	1.3	.16	.30	.67	"
12344.....	.692	.82	.169	.020	.045	1.3	.13	.29	.61	"
4921.....	.714	.86	.154	.028	.036	1.4	.07	.32	.32	"
10712.....	.696	.81	.113	.016	.034	1.6	.12	.34	.55	"
5200.....	.680	.83	.190	.035	.035	1.4	.16	.31	.64	"
11640.....	.660	.82	.142	.016	.034	1.4	.20	.28	.82	"
4922.....	.696	.89	.161	.018	.038	1.3	.07	.31	.31	"
4919.....	.740	.90	.139	.026	.042	1.3	.17	.26	.75	"
10713.....	.718	.90	.184	.025	.050	1.3	.12	.29	.59	12-13-10
12346.....	.660	.84	.174	.018	.045	1.3	.14	.28	.68	"
10714.....	.667	.81	.141	.017	.030	1.4	.08	.32	.41	"
12347.....	.640	.74	.125	.017	.035	1.4	.20	.30	.78	"
11643.....	.748	.92	.143	.026	.042	1.3	.06	.28	.34	"
8785.....	.730	.85	.141	.021	.040	1.3	.06	.27	.27	"

CONDENSED SHEET NO. 2.

100-lb. N. Y. C. Basic Open-Hearth Rails, Lackawanna, 1910 and 1911, 20-ft. Drop.

	Chemical Composition.						Elongation.			
Melt No.	C.	Mn.	Sil.	Phos.	Sul.	Per Set.	Max. Per In.	Total 6 In. Single Blow.	Total Exhausted for 6 In.	Date.
3903.....	.690	.88	.125	.029	.037	1.3	.18	.29	.79	12-26-10
7896.....	.623	.75	.136	.021	.036	1.5	.16	.34	.76	"
1880.....	.732	.76	.132	.019	.030	1.4	.13	.30	.62	"
10740.....	.692	.76	.158	.018	.043	1.3	.14	.28	.62	"
5227.....	.622	.75	,102	.017	.034	1.6	.15	.32	.72	"
7897.....	.724	.86	.117	.018	.044	1.3	.16	.27	.63	"
3905.....	.686	.89	.121	.032	.038	1.2	.08	.28	.41	"
9049.....	.668	.76	.110	.039	.047	1.5	.20	.33	.88	"
2710.....	.644	.81	.108	.017	.029	1.3	.18	.29	.75	"
8807.....	.692	.74	.133	.017	.032	1.3	.18	.27	.79	"
4944.....	.642	.73	.131	.014	.029	1.4	.14	.29	.63	"
3904.....	.658	.81	.125	.023	.031	1.4	.16*	.30†	.76	"
5226.....	.674	.80	.137	.019	.040	1.4	.18	.30	.78	"
5228.....	.650	.82	.121	.021	.038	1.4	.18	.30‡	.79	12-27-10
5228.....	.650	.82	.121	.021	.038	1.5	.15	.24‡	.64	"
1881.....	.676	.75	.125	.021	.040	1.3	.21	.31‡	.87	"
1881.....	.676	.75	.125	.021	.040	1.4	.15	.32‡	.71	"
3908.....	.680	.82	.184	.029	.033	1.3	.21	.29	.85	"
4945.....	.624	.72	.136	.018	.032	1.5	.21	.33	.97	"
12369.....	.688	.79	.125	.018	.032	1.4	.20	.34	.89	"
3907.....	.690	.79	.122	.020	.041	1.4	.14	.30	.71	"
4946.....	.726	.77	.110	.018	.042	1.3	.15	.26	.70	"
10742.....	.672	.81	.110	.016	.030	1.4	.15	.29	.72	"
1882.....	.748	.82	.132	.032	.038	1.2	.13	.25	.56	"
8809.....	.690	.84	.136	.023	.033	1.4	.08	.30	.42	"

*Spec. †Blue E. ‡Ft. OH.

CONDENSED SHEET NO. 3.

80-lb. N. Y. C. Basic Open-Hearth Rails, Lackawanna, 1911, 18-ft. Drop.

Melt No.	Chemical Composition. C.	Mn.	Sil.	Phos.	Sul.	Elongation. Per Set.	Max. Per In.	Total 6 In. Single Blow.	Total Exhausted for 6 In.	Date.
5287.....	.655	.87	.145	.015	.033	2.0	.21	.42	1.22	2-1-11
12414.....	.670	.84	.117	.020	.048	1.8	.20	.36	.97	"
4020.....	.649	.90	.155	.020	.049	2.0	.23	.38	1.12	"
3987.....	.595	.91	.148	.020	.044	2.1	.20	.41	1.10	"
7977.....	.643	.91	.141	.017	.040	1.8	.20	.37	.95	"
2771.....	.660	.90	.145	.018	.048	2.0	.21	.37	.92	"
10816.....	.632	.88	.117	.020	.038	1.9	.20	.39	.86	"
1958.....	.672	.90	.141	.022	.045	1.9	.20	.32	.81	"
9135.....	.615	.86	.108	.019	.048	2.0	.22	.38	.99	"
6169.....	.635	.89	.139	.023	.038	1.8	.23	.38	1.03	"
5288.....	.618	.81	.159	.019	.038	2.0	.22	.44	1.07	"
7978.....	.603	.79	.156	.022	.034	1.9	.24	.44	1.13	"
2772.....	.611	.83	.121	.023	.035	2.0	.18	.38	.83	"
10817.....	.620	.90	.141	.024	.048	1.9	.22	.42	.96	"
1959.....	.674	.88	.149	.026	.035	1.7	.16	.38	.73	"
12416.....	.680	.86	.180	.020	.040	1.7	.21	.36	.85	"
8876.....	.624	.76	.128	.038	.045	1.9	.18	.41	.91	"
5289.....	.610	.90	.110	.022	.042	1.8	.20	.33	.95	"
7979.....	.621	.86	.128	.018	.035	1.8	.19	.38	.85	"
2773.....	.615	.81	.122	.017	.040	2.0	.22	.40	1.12	2-2-11
1960.....	.662	.93	.122	.020	.045	1.8	.18	.38	.97	"
11718.....	.679	.96	.128	.018	.045	1.7	.19	.33	.80	"
6170.....	.595	.83	.117	.015	.038	1.9	.19	.35	.88	"
8877.....	.635	.90	.141	.018	.046	1.8	.17	.34	1.09	"
7980.....	.638	.90	.141	.038	.058	1.8	.18	.34	1.06	"

CONDENSED SHEET NO. 4.

100-lb. L. S. & M. S. Basic Open-Hearth Rails, Bethlehem, 1911, 20-ft. Drop.

Melt No.	Chemical Composition. C.	Mn.	Sil.	Phos.	Sul.	Elongation. Per Set.	Max. Per In.	Total 6 In. Single Blow.	Total Exhausted for 6 In.	Date.
B-19806...	.75	.93	.144	.033	.040	1.1	.07	.23	.30	4-3-11
B-21882...	.73	.95	.195	.039	.046	1.2	.04	.15	.15	Rejected
B-20845...	.68	.73	.180	.028	0.39	1.35	.06	.26	.30	4-3-11
B-23623...	.71	.70	.136	.025	.045	1.30	.08	.24	.39	"
B-19807...	.63	.70	.130	.024	.040	1.55	.25	.32	1.17	"
B-17939...	.66	.75	.120	.024	.032	1.30	.17	.28	.77	"
B-23624...	.63	.72	.129	.035	.051	1.25	.10	.27	.53	"
B-21881...	.73	.70	.115	.018	.046	1.45	.21	.30	.93	"
B-14969...	.65	.80	.106	.027	.041	1.30	.14	.25	.85	"
B-22747...	.67	.70	.138	.030	.037	1.20	.08	.26	.42	"
B-18875...	.68	.99	.156	.035	.050	1.01	.04	.13	.13	(Rejected)
B-22748...	.62	.72	.110	.024	.042	1.50	.07	.33	.35	4-3-11
B-14970...	.73	.85	.137	.021	.036	1.40	.08	.29	.40	4-4-11
B-23625...	.69	.95	.142	.024	.048	1.20	.06	.24	.28	"
B-16930...	.75	.78	.128	.023	.032	1.25	.13	.27	.59	"
B-21883...	.63	.72	.128	.032	.051	1.30	.13	.29	.55	"
B-15806...	.75	.73	.100	.024	.031	.85	05-05	.19	.25	"
B-15806...	.75	.73	.100	.024	.031	1.15	.06§	.28¶	.28	"
B-18876...	.68	.70	.120	.035	.040	.95	.04‡	.20	.22	"
B-18876...	.68	.70	.120	.035	.040	1.15	.07§	.25‖	.30	(Rejected)
B-18877...	.70	.03	.121	.017	.027	1.10	.14§	.25	.02	"
B-14971...	.72	.70	.195	.025	.037	1.15	.08§	.27	.45	"
B-17941...	.67	.82	.185	.020	.029	1.15	.12	.22	.53	"
B-15807...	.70	.85	.134	.020	.028	1.20	.11	.23	.52	"
B-22749...	.75	.92	.130	.032	.041	1.15	.09	.25	.41	"
B-21884...	.66	.79	.122	.035	.045	1.20	.10	.24	.43	"

§Retest. ¶O. K. ‖"A" Rail.

CONDENSED SHEET NO. 5.

100-lb. L. S. & M. S. Basic Open-Hearth Rails, Bethlehem, 1911, 20-ft. Drop.

	Chemical Composition.					Elongation.				
Melt No.	C.	Mn.	Sil.	Phos.	Sul.	Per Set.	Max. Per In.	Total 6 In. Single Blow.	Total Exhausted for 6 In.	Date.
B-19817...	.74	.80	.196	.035	.035	1.35	.17	.24	.84	4-8-11
B-21983...	.69	.72	.200	.031	.033	1.30	.20	.23	.88	"
B-17949...	.73	.71	.135	.026	.037	1.30	.14	.25	.60	"
B-19818...	.75	.90	.135	.037	.047	1.25	.15	.24	.70	"
B-14979...	.66	.79	.177	.039	.043	1.30	.10	.26	.45	"
B-21895...	.64	.80	.156	.039	.038	1.40	.21	.27	1.05	"
B-19815...	.68	.71	.102	.025	.050	1.40	.10	.26	.51	"
B-19819...	.70	.72	.185	.035	.042	1.40	.15	.28	.75	"
B-17951...	.73	.81	.198	.034	.043	1.40	.11	.29	.51	"
B-18883...	.73	.90	.146	.039	.054	1.65	.20	.32	.94	"
B-22760...	.67	.72	.108	.035	.045	1.55	.18	.25	.78	"
B-14985...	.62	.82	.108	.028	.038	1.35	.17	.24	.78	4-10-11
B-18888...	.64	.70	.109	.027	.056	1.35	.16	.24	.71	"
B-17954...	.68	.89	.110	.026	.056	1.35	.21	.24	.82	"
B-21901...	.63	.72	.103	.024	.052	1.50	.22	.26	1.09	"
B-21902...	.64	.71	.108	.025	.038	1.35	.12	.25	.53	"
B-22766...	.65	.75	.118	.036	.045	1.40	.11	.26	.52	"
B-21903...	.62	.70	.106	.031	.051	1.50	.24	.31	.98	"
B-15825...	.70	.74	.117	.034	.033	1.45	.20	.28	.88	"
B-14986...	.75	.73	.118	.022	.030	1.30	.09	.20	.38	"
B-19826...	.72	.77	.134	.040	.053	1.50	.10	.29	.48	"
B-17957...	.69	.72	.107	.027	.050	1.55	.21	.28	.98	"
B-22769...	.62	.77	.121	.033	.049	1.50	.22	.27	1.05	"
B-14987...	.70	.81	.142	.034	.058	1.50	.22	.30	1.02	"

CONDENSED SHEET NO. 6.

100-lb. L. S. & M. S. Basic Open-Hearth Rails, Gary, 1911, 20-ft. Drop.

	Chemical Composition.					Elongation.				
Melt No.	C.	Mn.	Sil.	Phos.	Sul.	Per Set.	Max. Per In.	Total 6 In. Single Blow.	Total Exhausted for 6 In.	Date.
54072.....	.71	.87	.20	.029	.036	1.4	.06	.27	.27	2-23-11
43092.....	.73	.90	.20	.035	.047	1.3	.12	.28	.53	"
48095.....	.70	.76	.20	.027	.039	1.4	.16	.28	.79	"
51083.....	.70	.78	.18	.026	.037	1.4	.12	.29	.59	"
46079.....	.70	.80	.19	.022	.035	1.5	.18	.29	.85	"
49020.....	.70	.88	.20	.029	.030	1.3	.07	.25	.34	"
56066.....	.64	.90	.20	.040	.035	1.5	.18	.28	.81	"
55108.....	.67	.87	.20	.033	.037	1.4	.06	.28	.28	"
54073.....	.67	.90	.15	.027	.036	1.3	.15	.30	.72	"
46080.....	.72	.85	.20	.032	.032	1.2	.10	.25	.46	"
51084.....	.72	.88	.20	.028	.031	1.3	.06	.28	.28	"
43093.....	.66	.87	.19	.040	.043	1.4	.14	.27	.62	"
44103.....	.63	.90	.19	.040	.040	1.4	.09	.28	.39	"
45065.....	.67	.90	.20	.032	.037	1.4	.12	.26	.53	"
48096.....	.69	.85	.22	.029	.038	1.3	.12	.28	.52	"
47102.....	.71	.87	.19	.027	.034	1.2	.11	.26	.51	"
50109.....	.72	1.00	.23	.036	.033	1.3	.14	.25	.50	"
49021.....	.74	.95	.22	.037	.044	1.3	.07	.25	.27	"
54074.....	.68	.87	.20	.040	.040	1.4	.08	.27	.30	"
46081.....	.65	.90	.18	.036	.032	1.4	.06	.28	.30	"
53080.....	.63	.74	.18	.018	.033	1.5	.20	.29	.95	"
51085.....	.72	.80	.20	.029	.041	1.4	.14	.27	.73	2-24-11
50110.....	.65	.72	.14	.020	.042	1.4	.24	.31	1.05	"
43095.....	.73	.92	.18	.018	.038	1.4	.13	.28	.64	"

CONDENSED SHEET NO. 7.

100-lb. Mich. Cent. Basic Open-Hearth Rails, Gary, 1911, 20-ft. Drop.

	Chemical Composition.					Elongation.			
Melt No.	C.	Mn.	Sil.	Phos.	Sul.	Per Set.	Max. Per In.	Total 6 In. Single Blow.	Total Exhausted for 6 In.	Date.
53238	.74	.85	.13	.020	.044	1.3	.15	.27	.65	5-12-11
55244	.63	.73	.16	.029	.052	1.3	.18	.30	.64	"
44247	.75	1.00	.20	.039	.046	1.3	.15	.25	.69	"
52239	.68	.70	.20	.023	.033	1.4	.19	.27	.83	"
49182	.65	.85	.19	.035	0.40	1.4	.19	.31	.83	"
50252	.64	.80	.13	.034	.042	1.5	.17	.30	.86	"
47248	.70	.97	.15	.025	.033	1.4	.13	.27	.67	"
46248	.62	.75	.12	.025	.043	1.5	.18	.28	1.01	"
54225	.64	.80	.15	.024	.039	1.5	.15	.27	.72	"
45210	.73	.82	.15	.026	.043	1.5	.15	.27	.76	"
44248	.67	.85	.20	.030	.046	1.4	.15	.27	.72	"
52240	.72	.90	.19	.029	.038	1.3	.12	.25	.66	"
48228	.63	.82	.20	.025	.039	1.4	.17	.27	.82	"
50253	.67	.85	.18	.025	.038	1.6	.15	.29	.68	"
49183	.68	.82	.19	.025	.046	1.5	.14	.26	.77	"
56184	.68	.90	.19	.024	.042	1.4	.16	.26	.71	"
55245	.68	.82	.16	.025	.041	1.3	.10	.23	.45	"
46249	.71	.80	.19	.037	.047	1.5	.15	.27	.87	"
48229	.68	.98	.12	.036	.046	1.4	.12	.28	.55	"
50254	.68	.95	.18	.040	.039	1.4	.13	.28	.54	"
52241	.66	.81	.19	.025	.035	1.5	.17	.30	.80	"
44249	.69	1.00	.20	.039	.042	1.3	.15	.27	.55	"
56185	.75	.90	.20	.038	.039	1.3	.06	.24	.25	"

CONDENSED SHEET NO. 8.

90-lb. C., C., C. & St. L. Ry. Basic Open-Hearth Rails, Gary, 1911, 18-ft. Drop.

	Chemical Composition.					Elongation.			
Melt No.	C.	Mn.	Sil.	Phos.	Sul.	Per Set.	Max. Per In.	Total 6 In. Single Blow.	Total Exhausted for 6 In.	Date.
55136	.62	.78	.19	.023	.040	1.6	.16	.29	.48	3-11-11
51114	.62	.72	.17	.020	.037	1.6	.21	.32	.98	"
47131	.63	.88	.20	.034	.035	1.5	.19	.30	.87	"
46117	.65	.78	.20	.024	.037	1.6	.26	.34	1.13	"
45095	.68	.84	.18	.024	.044	1.5	.22	.30	.98	"
48122	.66	.92	.18	.027	.038	1.6	.18	.29	.80	"
45094	.73	.75	.19	.023	.041	1.5	.09	.31	.41	"
49052	.70	.93	.20	.037	.046	1.7	.22	.33	.99	"
43120	.65	.79	.16	.032	0.53	1.6	.15	.31	.71	"
46116	.62	.74	.13	.023	.038	1.6	.21	.35	1.08	"
56096	.61	.70	.15	.023	0.32	1.6	.14	.33	.63	"
53112	.70	.85	.18	.029	.046	1.5	.09	.20	.38	"
52107	.68	.83	.17	.026	.039	1.4	.16	.28	.71	"
55137	.61	.95	.18	.040	.044	1.6	.09	.30	.35	"
50165	.63	.78	.13	.022	.044	1.7	.22	.33	1.12	3-23-11
52134	.65	.76	.17	.023	.036	1.4	.17	.28	.76	"
56116	.66	.80	.15	.026	.045	1.6	.16	.36	.87	"
43145	.70	.83	.16	.023	.048	1.5	.20	.30	.87	"
47152	.71	.87	.16	.025	.041	1.4	.16	.30	.75	"
51139	.67	.86	.13	.027	.045	1.5	.15	.28	.75	"
46144	.73	.87	.20	.024	.047	1.4	.12	.28	.47	"
44142	.63	.70	.16	.021	.041	1.6	.17	.33	.80	"
49081	.64	.82	.20	.030	.051	1.6	.20	.30	.86	"
55159	.66	.70	.13	.026	.049	1.6	.16	.29	.74	"

CONDENSED SHEET NO. 9.

85-lb. C., I. & S. Ry. Basic Open-Hearth Rails, Gary, 1911, 18-ft. Drop.

	Chemical Composition.					Elongation.			
Melt No.	C.	Mn.	Sil.	Phos.	Sul.	Per Set.	Max. Per In.	Total 6 In. Single Blow.	Total Exhausted for 6 In.	Date.
43133.....	.66	.89	.20	.033	.036	1.5	.12	.29	.56	3-18-11
52122.....	.68	.85	.20	.031	.038	1.6	.17	.29	.76	"
51127.....	.64	.80	.20	.028	.038	1.6	.19	.31	.88	"
50154.....	.64	.93	.20	.039	.035	1.5	.18	.29	.78	"
54117.....	.68	.90	.20	.030	.036	1.5	.13	.27	.77	"
44127.....	.73	.83	.20	.030	.037	1.5	.14	.27	.70	"
56108.....	.65	.80	.20	.029	.042	1.5	.15	.31	.65	"
53127.....	.73	.84	.20	.029	.041	1.5	.09	.28	.39	"
46132.....	.62	.95	.20	.040	.044	1.7	.20	.31	.93	"
44191.....	.73	.88	.20	.035	.046	1.5	.11	.29	.49	4-14-11
56159.....	.73	.85	.19	.028	.038	1.6	.12	.27	.59	"
50194.....	.73	.93	.15	.027	.036	1.6	.12	.30	.51	4-4-11
48169.....	.71	.70	.12	.026	.036	1.7	.13	.29	.65	"
52182.....	.69	.76	.13	.036	.043	1.7	.16	.30	.68	4-14-11
46190.....	.71	.90	.17	.031	.039	1.6	.13	.31	.59	"
51184.....	.62	.77	.18	.027	.042	1.9	.11	.33	.57	"
44192.....	.72	.83	.13	.040	.030	1.7	.16	.32	.74	"
49130.....	.71	.79	.14	.027	.040	1.7	.17	.32	.76	4-15-11
45155.....	.71	.85	.19	.039	.046	1.5	.13	.25	.71	"
56160.....	.73	.82	.14	.026	.036	1.8	.17	.30	.73	"
47197.....	.71	.96	.13	.031	.030	1.7	.17	.30	.72	"
43189.....	.63	.87	.13	.029	.040	1.7	.15	.32	.93	"
52183.....	.60	.79	.16	.018	.029	1.8	.21	.35	.96	"

CONDENSED SHEET NO. 10.

80-lb. Peoria & Eastern Ry. Basic Open-Hearth Rails, Gary, 1911, 18-ft. Drop.

	Chemical Composition.					Elongation.			
Melt No.	C.	Mn.	Sil.	Phos.	Sul.	Per Set.	Max. Per In.	Total 6 In. Single Blow.	Total Exhausted for 6 In.	Date.
45110.....	.55	.70	.12	.015	.034	2.1	.26	.39	1.29	3-18-11
55149.....	.56	.77	.20	.032	.045	2.1	.22	.43	1.13	"
50155.....	.55	.88	.20	.040	.040	2.0	.17	.23	.78	"
49069.....	.57	.76	.12	.030	.050	2.2	.16	.40	.83	"
54196.....	.66	.73	.16	.020	.036	2.0	.18	.35	.90	4-28-11
44220.....	.62	.70	.14	.020	.034	2.0	.22	.30	1.08	"
50220.....	.64	.72	.17	.025	.040	2.2	.20	.37	1.10	"
53209.....	.68	.76	.15	.020	.040	2.3	.23	.36	1.10	"
52210.....	.59	.73	.12	.019	.034	2.2	.23	.33	1.01	"
48197.....	.65	.81	.19	.022	.038	2.0	.24	.35	.97	"
45182.....	.56	.70	.13	.025	.047	2.2	.25	.41	1.09	"
51211.....	.57	.70	.13	.024	.038	1.9	.17	.34	.86	"
55214.....	.65	.78	.16	.021	.040	2.3	.23	.38	1.06	"
46218.....	.63	.88	.19	.028	.048	2.0	.22	.37	1.02	"
43214.....	.56	.80	.15	.021	.040	2.2	.23	.43	1.08	"
49157.....	.61	.80	.18	.020	.044	2.0	.17	.33	.70	"
44221.....	.65	.78	.16	.025	.036	2.0	.18	.34	.84	"
50221.....	.67	.85	.18	.023	.036	2.3	.18	.39	.88	"
54197.....	.65	.78	.17	.025	.043	2.0	.16	.31	.65	"
46223.....	.63	.75	.18	.022	.041	1.7	.21	.41	.98	"
47227.....	.55	.75	.14	.025	.034	1.7	.12	.25	.54	5-1 11
48203.....	.61	.84	.19	.026	.044	1.9	.18	.38	.81	"
49162.....	.60	.73	.13	.021	.041	2.2	.21	.48	.94	"

OFFICE OF CONSULTING ENGINEER, RAILS, TIRES AND STRUCTURAL STEEL.

GRAND CENTRAL TERMINAL
NEW YORK

Form C. E. O. No. 1.

DUCTILITY AND ELONGATION TESTS.

Sheet No. 1

Basic Open Hearth Rails 100 lbs. per yd. 1001 Section. Moment of Inertia 48.5 4th Power inches
Manufactured by Lackawanna Steel Co. for N.Y.C. & H. R.R. Date Rolled Dec. 27th, 10.
Ht. of Drop 20 ft Tup 2000 lbs. Supports 3 ft Centers. Ingots 19 by 19 inches
Teemed in 3 Rail Lengths. Blooms Cut None Reheated No Rolled in 3 Rail Lengths

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.
1881	108	36	27th	.676	.75	.125	.021	.040	

Ingot No.	No. of Drop	Permt. Set Inches	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.3	1.04	1.06	1.07	1.05	1.05	1.04	6.31	
	2	2.4	1.08	1.12	1.14	1.10	1.09	1.06	6.59	
	3	3.6	1.11	1.16	1.19	1.15	1.13	1.08	6.82	
	4	Broke	1.13	1.17	1.21	1.16	1.13	1.08	6.87	
18	1	1.4	1.04	1.05	1.07	1.06	1.07	1.04	6.33	
36	1	Broke	1.05	1.05	1.03	1.05	1.04	1.03	6.25	Chilled Test
	1	1.3	1.04	1.05	1.05	1.05	1.04	1.04	6.27	Retest
	2	Broke	1.04	1.05	1.08	1.10	1.11	1.07	6.45	" "
1	1	1.3	Mill Test Drop 18 ft.							

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.
1881	108	36	27th	.676	.75	.125	.021	.040	

Ingot No.	No. of Drop	Permt. Set	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
18	1	1.4	1.03	1.07	1.06	1.06	1.06	1.04	6.32	Duplicate Test
	2	2.6	1.06	1.13	1.12	1.11	1.10	1.06	6.58	" "
	3	3.7	1.08	1.15	1.15	1.13	1.12	1.08	6.71	" "
	4	Broke	1.08	1.15	1.15	1.13	1.12	1.08	6.71	" "
18	1	1.4	1.04	1.06	1.06	1.06	1.06	1.03	6.31	Top of "C" rail
	2	Sheared	1.04	1.06	1.06	1.06	1.06	1.03	6.31	" " "
18	1	1.4	1.04	1.05	1.06	1.05	1.07	1.04	6.31	Bottom of "C" rail
	2	2.6	1.06	1.09	1.11	1.12	1.13	1.11	6.62	
	3	Broke	1.08	1.13	1.17	1.19	1.16	1.11	6.84	

NOTE:
Melt number 1881 Special F.T. Open Hearth Steel

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GRAND CENTRAL TERMINAL
NEW YORK

Form C. E. O. No. 1.

DUCTILITY AND ELONGATION TESTS. Sheet No. 2

Basic Open Hearth Rails 100 lbs. per yd 1001 Section. Moment of Inertia 48.5 4th Power inches
Manufactured by Lackawanna Steel Co., for N.Y.C. & H.R.R. Date Rolled Dec. 27th, 10.
Ht. of Drop 20 ft Tup 2000 lbs., Supports 3 ft Centers. Ingots 19 by 19 inches
Teemed in 3 Rail Lengths. Blooms Cut No Reheated No Rolled in 3 Rail Lengths

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
5228	101	34	27th	.650	.82	.121	.021	.038		

Ingot No.	No. of Drop	Permt. Set Inches	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.4	1.04	1.07	1.06	1.05	1.05	1.03	6.30	
	2	2.4	1.05	1.12	1.12	1.11	1.09	1.06	6.55	
	3	Broke	1.10	1.18	1.18	1.15	1.11	1.07	6.79	
18	1	1.4	1.04	1.05	1.06	1.05	1.06	1.04	6.30	
	2	2.4	1.07	1.10	1.13	1.10	1.10	1.07	6.57	
	3	Broke	1.08	1.13	1.13	1.12	1.10	1.07	6.63	
33	1	1.3	1.05	1.05	1.05	1.05	1.06	1.05	6.31	
	2	2.4	1.07	1.10	1.12	1.11	1.10	1.07	6.57	
	3	3.5	1.12	1.13	1.14	1.12	1.10	1.07	6.68	
	4	Broke	1.12	1.13	1.14	1.12	1.10	1.07	6.68	
1	1	1.3	Mill	test	Drop	18	ft.			

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
5228	101	34	27th	.650	.82	.121	.021	.038		

Ingot No.	No. of Drop	Permt. Set	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
18	1	1.5	1.03	1.05	1.05	1.07	1.03	1.01	6.24	Top of "C" rail
	2	2.7	1.05	1.08	1.10	1.13	1.10	1.03	6.49	" " " "
	3	3.9	1.08	1.11	1.13	1.14	1.11	1.04	6.61	" " " "
	4	Broke	1.08	1.12	1.13	1.15	1.12	1.04	6.64	" " " "
18	1	1.5	1.05	1.05	1.06	1.06	1.07	1.04	6.33	Bottom of "C" rail
	2	2.8	1.07	1.10	1.12	1.11	1.11	1.08	6.59	" " " "
	3	4.2	1.08	1.12	1.13	1.13	1.13	1.09	6.68	" " " "
	4	Broke	1.08	1.12	1.13	1.13	1.13	1.09	6.68	" " " "

NOTE-

Melt number 5228 Special F. T. Basic Open Hearth Steel.

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GRAND CENTRAL TERMINAL
NEW YORK

Form C. E. O. No 1.

DUCTILITY AND ELONGATION TESTS. Sheet No. 3

Basic Open Hearth Rails 100 lbs. per yd. 1001 Section. Moment of Inertia 48.5 4th Power inches
Manufactured by Lackawanna Steel Co., for N.Y.C. & H.R.R. Date Rolled Dec. 26th, 10.
Ht. of Drop 20 ft. Tup 2000 lbs., Supports 3 ft. Centers, Ingots 19 by 19 inches
Teemed in 3 Rail Lengths. Blooms Cut No Reheated None Rolled in 3 Rail Lengths

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
3904	96	32	26th	.658	.81	.125	.023	.031		

Ingot No.	No. of Drop	Permt. Set Inches	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	Broke	1.04	1.03	1.04	1.05	1.04	1.02	6.22	Chilled Test
		"	1.01	1.03	1.04	1.03	1.01	1.02	6.14	Retest failed
18	1	1.4	1.05	1.06	1.07	1.05	1.05	1.03	6.31	
34	1	1.4	1.03	1.05	1.05	1.06	1.06	1.05	6.30	
	2	2.5	1.06	1.10	1.11	1.13	1.10	1.07	6.57	
	3	Sheared	1.08	1.14	1.16	1.16	1.13	1.09	6.76	
1	1	1.2	Mill	test	Drop	18	ft.			

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
5226	96	32	26th	.674	.80	.137	.019	.040		

Ingot No.	No. of Drop	Permt. Set	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.3	1.05	1.05	1.07	1.05	1.05	1.03	6.30	
	2	2.4	1.07	1.08	1.13	1.12	1.11	1.06	6.57	
	3	Broke	1.08	1.12	1.18	1.16	1.15	1.09	6.78	
32	1	1.4	1.05	1.05	1.07	1.05	1.05	1.03	6.30	
18	1	1.4	1.05	1.05	1.06	1.05	1.05	1.03	6.29	
1	1	1.2	Mill	test	Drop	18	ft.			

NOTE:
Melt No. 3904 failed on N.Y.C. test and was designated (special)
Ends painted blue.

M. E. Biggs
Inspector

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Form C. E. O. No. 1.

DUCTILITY AND ELONGATION TESTS. Sheet No. 4

Basic Open Hearth Rails 100 lbs. per yd. 10001 Section. Moment of Inertia 43.8 4th Power inches
Manufactured by Ill. Steel Co., Gary for Mich. Cent. Date Rolled May 25th, 11.
Ht. of Drop 20 ft. Tup 2000 lbs., Supports 3 ft. Centers. Ingots 20 by 24 inches
Teemed in 6 Rail Lengths. Blooms Cut two Reheated No Rolled in 2-3 Rail Lengths

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
46270	138	23	5/25	.62	.89	.15	.036	.056		
Ingot No.	No. of Drop	Permt. Set Inches	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.5	1.03	1.05	1.05	1.06	1.05	1.04	6.28	Temperature 90° #18
11	1	1.5	1.05	1.05	1.05	1.05	1.05	1.04	6.29	
23	1	1.3	1.03	1.05	1.05	1.05	1.05	1.04	6.27	
	2	2.3	1.07	1.10	1.10	1.10	1.08	1.06	6.51	
	3	Broke	1.08	1.11	1.12*	1.10	1.08	1.06	6.55	

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
50275	144	24	5/25	.68	.98	.20	.036	.037		
Ingot No.	No. of Drop	Permt. Set	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.3	1.03	1.04	1.05	1.05	1.04	1.03	6.24	Temperature 90°
	2	2.4	1.03	1.06	1.08	1.10	1.11	1.09	6.47	#19
	3	Broke	1.05	1.06	1.08	1.10	1.11	1.09	6.49	
12	1	1.4	1.03	1.05	1.05	1.05	1.04	1.03	6.25	
24	1	1.6	1.04	1.05	1.05	1.05	1.05	1.05	6.29	

NOTE:

P. C. Dempsey

Inspector.

OFFICE OF CONSULTING ENGINEER, RAILS, TIRES AND STRUCTURAL STEEL.

NEW YORK CENTRAL LINES

GRAND CENTRAL TERMINAL
NEW YORK

Form C. E. O. No. 1.

DUCTILITY AND ELONGATION TESTS. Sheet No. 5

Basic Open Hearth Rails 100 lbs. per yd. 10001 Section. Moment of Inertia 43.84th Power inches
Manufactured by Ill. Steel Co., Gary for Mich. Cent. Date Rolled June 7th, 1911
Ht. of Drop 20 ft. Tup 2000 lbs., Supports 3 ft. Centers. Ingots 20 by 24 inches
Teemed in 6 Rail Lengths. Blooms Cut 2 Reheated None Rolled in 2 - 3 Rail Lengths

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
54271	132	22	6/7	.67	.80	.15	.026	.042		

Ingot No.	No. of Drop	Permt. Set Inches	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.6	1.04	1.05	1.06	1.07	1.05	1.04	6.31	Temp. 68° #26
11	1	1.6	1.05	1.05	1.06	1.05	1.05	1.04	6.30	
	2	2.9	1.08	1.11	1.15	1.20	1.13	1.09	6.76	
	3	4.1	1.09	1.15	1.17	1.22	1.18	1.12	6.93	
	4	Broke	1.10	1.15	x1.20	1.22	1.18	1.12	6.97	
22	1	1.6	1.04	1.05	1.06	1.06	1.05	1.03	6.29	

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
51281	144	24	6/7	.63	.73	.12	.022	.049		

Ingot No.	No. of Drop	Permt. Set	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.7	1.05	1.07	1.07	1.06	1.05	1.05	6.35	Temp. 68° #27
12	1	1.6	1.04	1.05	1.07	1.07	1.06	1.05	6.34	
24	1	1.6	1.05	1.05	1.06	1.05	1.05	1.04	6.30	
	2	2.9	1.10	1.12	1.13	1.17	1.14	1.10	6.76	
	3	Broke	1.12	1.14	1.15	1.17*	1.14	1.10	6.82	

NOTE:

P. C. Dempsey
Inspector.

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NEW YORK CENTRAL LINES

GRAND CENTRAL TERMINAL
NEW YORK

Form C. E. C. No. 1.

DUCTILITY AND ELONGATION TESTS. Sheet No. 6

Basic Open Hearth Rails 100 lbs. per yd. 10001 Section. Moment of Inertia 43.8 4th Power inches
Manufactured by Ill. Steel Co., Gary for Mich. Cent. Date Rolled March 9th, 11.
Ht. of Drop 20 ft. Tup 2000 lbs., Supports 3 ft. Centers. Ingots 20 by 24 inches
Teemed in 6 Rail Lengths. Blooms Cut 2 Reheated None Rolled in 2 -3 Rail Lengths

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
48120	105	24	3/9	.70	.88	.19	.024	.041		

Ingot No.	No. of Drop	Permt. Set Inches	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.4	1.03	1.05	1.06	1.06	1.05	1.03	6.28	Temperature 46°
12	1	1.4	1.03	1.04	1.06	1.06	1.05	1.04	6.28	
	2	2.4	1.04	1.09	1.11	1.11	1.10	1.07	6.52	
	3	Broke	1.05	1.09	1.13	1.17	1.15	1.11	6.70	
24	1	1.4	1.03	1.05	1.05	1.06	1.05	1.03	6.27	

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
52104	141	24	3/9	.72	.80	.16	.023	.040		

Ingot No.	No. of Drop	Permt. Set	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.4	1.03	1.05	1.06	1.06	1.05	1.03	6.28	Temperature 45°
12	1	1.4	1.03	1.04	1.05	1.06	1.05	1.03	6.26	
24	1	1.4	1.03	1.05	1.06	1.06	1.05	1.03	6.28	
	2	2.5	1.04	1.06	1.09	1.11	1.12	1.08	6.50	
	3	Broke	1.05	1.08	1.09	1.17	1.20	1.15	6.74	

NOTE:

P. C. Dempsey
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GRAND CENTRAL TERMINAL
NEW YORK

Form C. E. O. No. 1.

DUCTILITY AND ELONGATION TESTS. Sheet No. 7

Basic Open Hearth Rails .85 lbs. per yd. 8504 Section. Moment of Inertia 30.0 4th Power inches
Manufactured by Ill. Steel Co., Gary for I. H. Belt Date Rolled May 31st, 11.
Ht. of Drop 18 ft. Tup 2000 lbs., Supports 3 ft. Centers. Ingots 20 by 24 inches
Teemed in 7 Rail Lengths. Blooms Cut 2 Reheated No Rolled in 3 & 4 Rail Lengths

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
56218	161	23	5/31	.70	.74	.15	.022	.033		

Ingot No.	No. of Drop	Permt. Set Inches	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.7	1.03	1.04	1.05	1.07	1.05	1.04	6.28	Temperature 59°
11	1	1.7	1.03	1.04	1.05	1.06	1.05	1.04	6.27	
	2	3.0	1.06	1.08	1.12	1.13	1.11	1.07	6.57	
	3	Broke	1.06	1.09	1.13	1.15	1.15	1.09	6.67	
23	1	1.7	1.03	1.04	1.05	1.06	1.05	1.03	6.26	

Melt No.	No. of Rails	No. of Ingots	Date	C.	Mn.	Sil.	Ph.	Sul.	Cu.	
50287	168	24	5/31	.69	.85	.16	.022	.033		

Ingot No.	No. of Drop	Permt. Set	Elongation per Inch 1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	Total	Remarks
2	1	1.7	1.03	1.05	1.06	1.07	1.05	1.03	6.29	Temperature 50°
12	1	1.7	1.03	1.04	1.06	1.07	1.06	1.04	6.30	
24	1	1.7	1.03	1.04	1.06	1.06	1.05	1.03	6.27	
	2	2.9	1.05	1.07	1.10	1.11	1.08	1.06	6.47	
	3	Broke	1.09	1.11	1.12	1.13	1.10	1.08	6.63	

NOTE:

P. C. Dempsey
Inspector.

Appendix B.

ABRASION TESTS OF RAILS ON REVOLVING MACHINE.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

Various tests were made in 1910 of rails made in a number of different mills and portions of these rails were later used to make abrasion tests on a "revolving machine." The mills at which the rails were made are shown below. The other tests referred to were published in the Proceedings of the American Railway Engineering and Maintenance of Way Association for 1911, Vol. 12, Part 2, and the pages of the Proceedings on which the results are reported are also shown below.

Maker.	Kind of Steel.	Pages.
Maryland Steel Co.	Bessemer, low phosphorus	387-398
Lackawanna Steel Co.	Bessemer, titanium	399-412
Ill. Steel Co., So. Works.	Bessemer	413-427
Ill. Steel Co., Gary.	Open-hearth	428-447
Carnegie Steel Co.	Bessemer	448-468

In all 20 rails were tested, and the "bottom" 10 ft. piece of each rail was set aside for the abrasion tests described in this report. Of these 20 rails, 18 were finally tested on the revolving abrasion machine. The work was done at the South Works of the Illinois Steel Co., who made the tests and kindly furnished all the facilities and labor needed for them.

REVOLVING MACHINE.

The machine consists of a circular track 20 ft. in diameter of the rails to be tested, and on the track ran two wheels, one at each end of a heavy beam which revolved with a large center pin. A sectional diagram of the machine is shown in Fig. 1 and a photograph of it set up is reproduced in Fig. 2. The vertical load of the wheels on the rail was obtained partly from the weight of the revolving beam and partly from the compression of the springs shown on the top of the beam. The dead load was about 11,500 lbs. per wheel and the spring compression had a capacity of 60,000 lbs. per wheel additional. A lateral pressure of the wheel on the rail was produced by means of springs which had a capacity

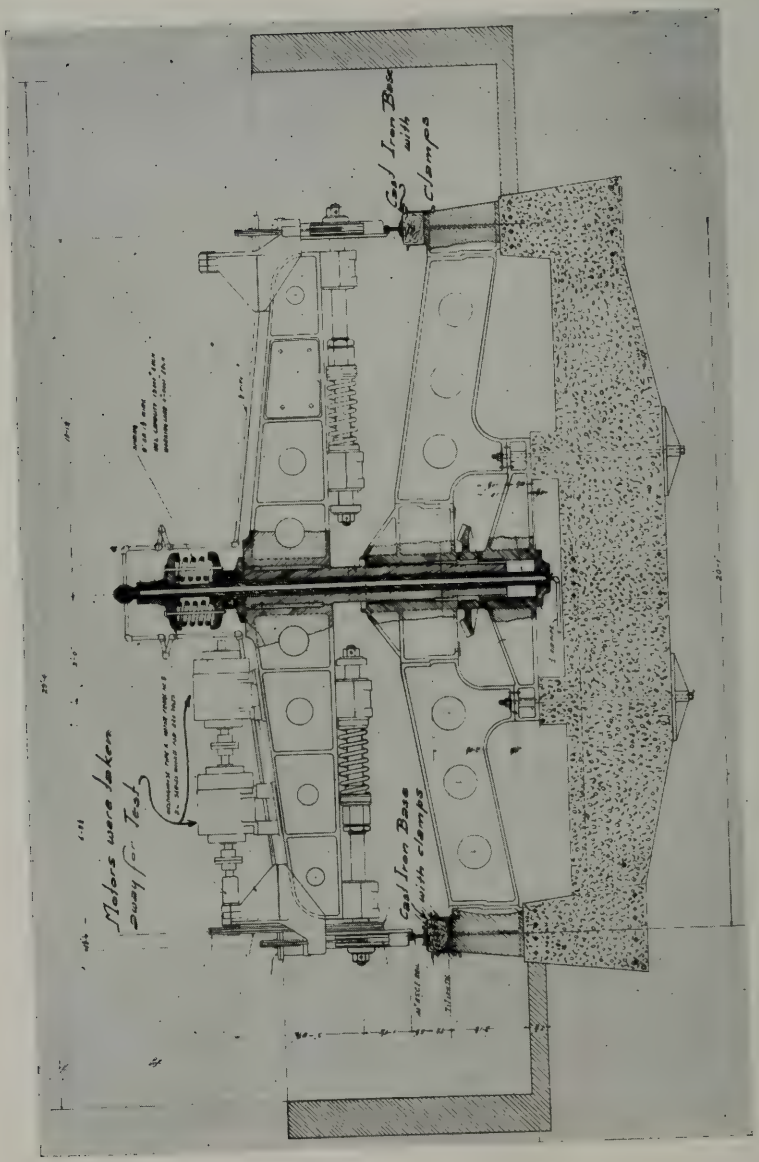

FIG. 1—DIAGRAM OF REVOLVING MACHINE.

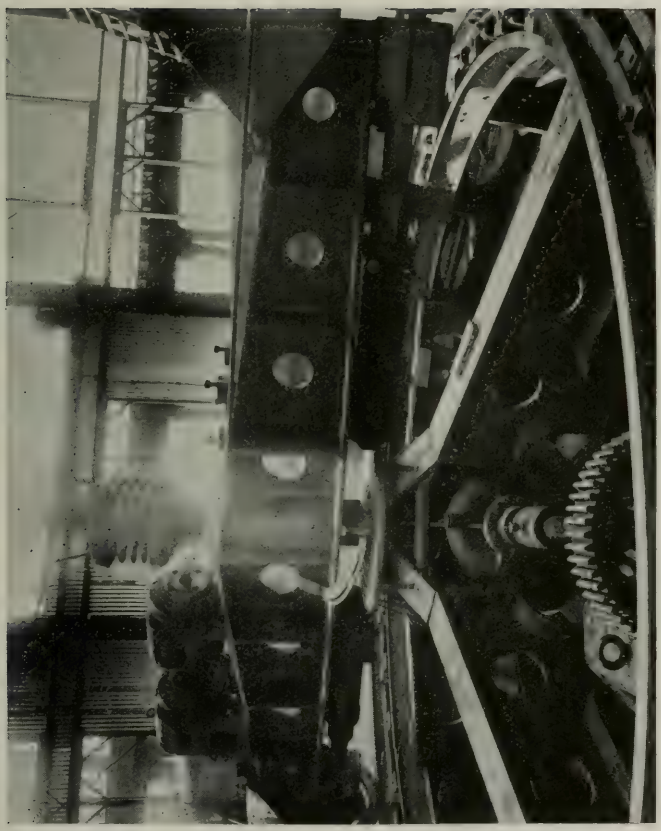

FIG. 2—VIEW OF REVOLVING MACHINE SET UP.

of 15,000 lbs. per wheel and the centrifugal force of the wheel was additional. The power to drive the machine was furnished by a 75 H.P. electric motor and was transmitted through a bevel gear to the center pin which then turned the beam. The two motors seen on top of the beam were not on the machine in these tests. The wheels were 33 inches in diameter, of the Master Car Builder's design and fitted with steel tires.

The 18 pieces of rail were tested in two lots and table 1 gives the data concerning the conditions of the tests.

TABLE 1—TEST CONDITIONS.

	Test 8.	Test 9.
Test started	6—9—1911	6—25—1911
Test finished	6—24—1911	7—6—1911
Time running	105 hrs. 36 min.	81 hrs. 35 min.
Total load, per wheel	13,750 lbs	17,750 lbs.
Side pressure	2,000 lbs.	1,000 lbs.
Revolutions	189,453	75,256
Additional side pressure	500 lbs.	1,000 lbs.
Date applied	6—23—1911	6—29—1911
Additional revolutions	16,549	74,959
Total revolutions	206,002	150,215

In Test 8 the tires were changed June 19, 1911, after 142,312 revolutions were made on the old tires. The South Chicago and Gary rails were tested together in Test 8 and the Maryland, Lackawanna and Carnegie rails were tested together in Test 9, but it will be noticed that the conditions were not the same in the two tests.

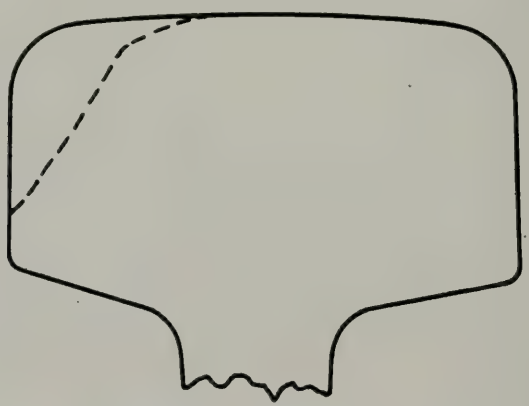

FIG. 3—SAMPLE DIAGRAM OF RAIL HEAD AFTER TESTING.

Each piece of rail tested was about 7 ft. long. One section diagram of the rail head was taken from each piece before starting the test, and after the test four diagrams were taken from each piece of rail. Fig. 3 is

given as a sample showing a rail head before and after testing, from which it will be noted that the wear on the rail simulates the wear in service of the outer rail on a curve.

Results of Tests.

The results of the abrasion tests, giving the square inches of metal worn away, are shown in table 2, covering the South Chicago and Gary rails, and in table 3 covering the Maryland, Lackawanna and Carnegie rails.

Table 2—Investigation 8—206,002 Revolutions.

Maker.	Ingot position.	Test number.	Wear, sq. in. 1	2	3	4	Av.
Ill. S. Co. So. Wks..	A	8—2	.357	.310	.346	.467	.370
	B	8—9	.403	.335	.370	.323	.358
	C	8—3	.623	.520	.645	.436	.556
		General average.....					.428
Ill. S. Co., Gary....	A	8—4	.414	.297	.332	.320	.341
	B	8—8	.295	.270	.296	.225	.272
	C	8—6	.363	.329	.253	.333	.320
	D	8—1	.299	.212	.308	.314	.283
	E	8—5	.361	.348	.287	.359	.339
	F	8—7	.328	.357	.221	.175	.270
		General average.....					.304

Table 3—Investigation 9—150,215 Revolutions.

Maker.	Ingot position.	Test number.	Wear, sq. in. 1	2	3	4	Av.
Md. St. Co.....	A	9—9	.401	.322	.449	.463	.409
	B	9—5	.447	.418	.465	.390	.430
	C	9—1	.381	.491	.436	.548	.464
		General average.....					.434
Lack. St. Co.....	A	9—3	.280	.437	.263	.301	.320
	B	9—2	.382	.346	.406	.292	.357
	D	9—7	.482	.463	.311	.356	.403
		General average.....					.360
Carn. St. Co.....	B	9—8	.304	.346	.325	.283	.315
	C	9—4	.318	.283	.349	.330	.320
	D	9—6	.291	.481	.362	.339	.368
		General average.....					.334

It should be remarked that the identification letter on each piece of rail, showing its position in the ingot, was cut off in preparing the rail for test and through oversight was not again re-marked on the rail. The ingot position was then determined after the test by etching a sample of each piece tested, and while the positions indicated in the tables are probably correct, there is a chance of error.

A general summary of the abrasion results for each make of rail per 100,000 revolutions is shown in table 4, together with the carbon, phosphorus and manganese contained in the rails, as shown by the original reports.

TABLE 4—SUMMARY.

Maker.	Test.	Carb.	Phos.	Mang.	Wear per 100,000 rev.
Ill. Steel Co., So. Wks.....	8	.51	.098	1.04	.208 sq. in.
Ill. Steel Co., Gary.....	8	.74	.043	.80	.148
Maryland Steel Co.....	9	.54	.049	.89	.289
Lackawanna Steel Co.....	9	.50	.097	.90	.240
Carnegie Steel Co.....	9	.52	.102	1.15	.223

The Maryland rails contained .37 copper, while the others were free from this element. As the conditions in Tests 8 and 9 were not alike, the two sets of tests are not comparable, and even the results on the rails in the same set vary so much in individual cases that comparison even here must be made guardedly.

In conclusion it may be said that this test indicates that Open-hearth steel of .74 per cent carbon wears away considerably slower under the conditions of this test than does Bessemer steel of .51 per cent carbon.

Appendix C.

INFLUENCE OF TITANIUM ON BESSEMER INGOTS AND RAILS.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report covers an investigation of the influence of titanium on ingots and rails made from Bessemer steel treated with ferro-titanium after blowing. A series of seven heats was made, treated with varying amounts of ferro-titanium; two of the heats were plain Bessemer steel and the other five were treated with .05 per cent., .1 per cent., .2 per cent., .4 per cent. and .6 per cent., respectively, of metallic titanium in the form of a cold 15 per cent. alloy. From each heat two ingots about 19 x 19 in. at the bottom and about 60 in. high were selected for this experimental work, one for splitting open and chemical survey, and the other to roll into 100-lb. rails. This work was done at Buffalo, N. Y., at the works of the Lackawanna Steel Company, who kindly furnished the steel and all the facilities for the investigation. The ferro-titanium used in these heats was kindly furnished by the Titanium Alloy Manufacturing Company, and the thanks and acknowledgments of the Rail Committee are due to the officers of these companies for thus very generously helping along this investigation.

One ingot of each pair was split open to note its interior condition and to make a chemical survey to determine the distribution of the various elements. The other ingot of each pair was rolled into 100-lb. rails of the P. S. (Pennsylvania Railroad System) section, and the entire rail-bar was then examined by means of drop tests, tension tests and cross-bending tests of the base.

MANUFACTURE.

The steel was made by blowing the mixer metal and scrap steel, adding the spiegel to the converter after blowing and holding the metal in the converter for 2½ minutes. It was then poured into the teeming ladle, the ferro-titanium being shoveled in at the same time, in the heats in which it was used. The heats that were treated with ferro-titanium were held in the ladle for 3 minutes and then poured into the molds. One of the plain heats was poured directly without holding in the ladle, and the other was held for 3 minutes the same as the titanium-treated steel. As ferro-titanium contains considerable carbon, the amount of spiegel was reduced in the titanium-treated heats, so as to keep a uniform carbon in the steel of about .50 per cent., and the manganese

was then kept up by the addition of ferro-manganese along with the ferro-titanium. The amounts in pounds of the various materials used are shown in table 1.

TABLE 1—AMOUNTS OF MATERIAL USED.

Test Heat No.	Mill Heat No.	Mixer Metal.	Scrap Steel.	Spiegel.	Ferro-Manganese.	Ferro-Titanium.
1	27,466	23,910	1,000	2,650	None	None
2	27,467	23,700	1,000	2,600	10	84
3	27,469	23,900	1,000	2,550	25	168
4	27,470	24,050	1,000	2,420	36	338
5	27,472	24,700	800	2,170	72	677
6	27,473	24,770	800	1,940	114	1,018
7	29,298	26,600	500	2,785	None	None

Heat No. 1 was a plain heat not held in the ladle. No. 2 was treated with .05 per cent. metallic titanium, No. 3 with .1 per cent., No. 4 with .2 per cent., No. 5 with .4 per cent., No. 6 with .6 per cent., and No. 7 was also a plain heat, but it was held in the ladle for 3 minutes before pouring into the molds. Heats 1 to 6, inclusive, were made October 25, 1911, and heat 7 was made November 30, 1911. The third and fourth ingots of the pouring were used for this investigation, the third for splitting and the fourth for rolling into rails, except in heat No. 7, from which the second and third ingots of the pouring were used. The ingots and rail-bars were given the same numerical test numbers as the heats from which they were made. The sample for the ladle analysis was taken in each case at the end of the pouring of the third ingot. The ingots from the titanium-treated steel all set quietly, with the tops either flat or slightly concave. The ingots of plain heat No. 1 bulged somewhat on top when setting, and those of plain heat No. 7 set flat on top. The molds had about a pint of tar poured into them before pouring the steel.

Special samples of the mixer metal and spiegel, and the regular heat samples, gave the results on analysis shown in table 2.

TABLE 2—ANALYSES.

	C.	P.	S.	Mn.	Si.	Ti.
Mixer, metal, av. 1 to 6 incl.	4.02	.086	.047	.83	1.77	....
Mixer, metal, heat 7.....	3.82	.090	.050	.83	1.87	....
Spiegel, heat 1.....	4.42	....	....	13.20	.....	....
Spiegel, heat 2.....	4.38	....	....	13.14	.....	....
Spiegel, heat 3.....	4.44	....	....	13.16	.....	....
Spiegel, heat 4.....	4.39	....	....	13.20	.....	....
Spiegel, heat 5.....	4.44	....	....	13.20	....	....
Spiegel, heat 6.....	4.40	....	....	13.09	.....	....
Spiegel, av. 1 to 6 incl....	.....	.071	.010	.....	1.45	....
Spiegel, heat 7.....	4.44	.072	.012	13.10	1.63	....

	C.	P.	S.	Mn.	Si.	Ti.
Ladle test, heat 1.....	.498	.087	.039	.92	.103	....
Ladle test, heat 2.....	.491	.087	.035	.86	.105	trace
Ladle test, heat 3.....	.504	.088	.038	.92	.098	trace
Ladle test, heat 4.....	.501	.088	.037	.92	.105	.021
Ladle test, heat 5.....	.495	.092	.040	.84	.107	.024
Ladle test, heat 6.....	.478	.090	.039	.89	.100	.021
Ladle test, heat 7.....	.482	.098	.042	1.04	.128	....

The ferro-titanium used gave the following results on analysis: titanium, 14.60 per cent.; iron, 74.10 per cent.; carbon, 7.24 per cent.; silicon, 1.87 per cent.; aluminum, 1.53 per cent.; manganese, .19 per cent.; phosphorus, .078 per cent.; magnesium, .11 per cent.; calcium, none.

After stripping, the ingots were placed in the soaking pit for about two hours, except those of heat No. 7, which were in the soaking pit 3 hours, 25 minutes. Those intended for splitting were then set aside to cool, and the others were rolled into 100-lb. rails. (P. S. Section of the Pennsylvania Railroad System, shown on page 147, Part 2, Vol. 12, 1911, Proc. Am. Ry. Eng. and M. W. Asso.). The ingots were bloomed to about 8x8 in. in 6 passes, and finished in 9 passes, making a total of 15 passes from the ingot to the rail with the one heating of the ingot. Only small discards were made from the ends of the blooms, and each rail-bar was cut into four rails, making no rail croppings from the ends of the bars. The weights of the bloom crops and the rails are shown in table 3. From rail-bar No. 7, a short piece, weighing 66 lbs., was cut from between the A and B rails, and this is included in the total weight shown in the table.

TABLE 3—WEIGHTS OF RAILS AND BLOOM CROPS, POUNDS.

	Rail-bar 1	Rail-bar 2	Rail-bar 3	Rail-bar 4	Rail-bar 5	Rail-bar 6	Rail-bar 7
Bloom crop, top....	253	120	158	130	126	121	91
Bloom crop, bottom	76	93	100	93	102	121	70
A rail	1,197	1,166	1,163	1,185	1,178	1,196	1,130
B rail	1,144	1,120	1,120	1,152	1,124	1,134	1,103
C rail	1,144	1,120	1,124	1,151	1,126	1,134	1,104
D rail	935	1,086	1,062	1,244	1,112	1,080	1,170
Total	4,749	4,705	4,727	4,955	4,768	4,786	4,734

INGOTS.

One ingot from each heat, after being soaked in the usual manner, was set aside to cool and was afterward split open to note its internal condition as to size and distribution of cavities, and to use for obtaining drillings with which to make a chemical survey of the ingot. The dimensions and weights of these ingots when cold are shown in table 4.

TABLE 4—INGOTS USED TO SPLIT OPEN.

Ingot No.	Titanium Treatment.	Hgt.	Bottom Dimensions.	Top Dimensions.	Weight Lbs.
1	None	58½	18 3-4 x 18 3-4	16 7-8 x 17 1-16	4,810
2	.05%	58¾	18 5-8 x 18 11-16	16 7-8 x 16 11-16	4,680
3	.1 %	58	18 5-8 x 18 11-16	16 13-16 x 16 15-16	4,810
4	.2 %	58¾	18 3-4 x 18 5-8	16 7-8 x 17	4,700
5	.4 %	61	18 7-8 x 18 7-8	16 7-8 x 16 3-4	4,830
6	.6 %	58⅞	18 13-16 x 18 13-16	17 x 16 13-16	4,980
7	None	59	18 9-16 x 18 11-16	16 3-4 x 16 3-4	4,900

Each ingot was cut in two a little to one side of a longitudinal axial plane, and then the larger part was planed down to the axial surface. These surfaces are shown in figures 1 to 7, inclusive. It will be noted that ingot 1, made of plain Bessemer steel, contained a large cavity in the upper part of the ingot, with a large number of small holes generally distributed in the upper 15 per cent. or so of the ingot, and with some of the holes close to the sides. Below the large cavity, there was also a condition of "honeycomb," tapering down to about the middle of the ingot. Ingot 2, made of metal treated with .05 per cent. metallic titanium, had a somewhat similar appearance, except that there were fewer of the small holes, and they were not so close to the sides of the ingot. Ingot 3, with .1 per cent. titanium treatment, contained a large tapering cavity extending from practically the top of the ingot to almost half-way down the ingot, with one "bridge" across the cavity. The small holes were almost entirely absent; that is, the metal was practically solid around the large interior cavity. Ingot 4, with .2 per cent. treatment, had a large tapering cavity running from close to the top of the ingot to below the middle, with a bridge across the cavity, and with solid metal around entirely free from small holes. Ingot 5, with .4 per cent. treatment, and ingot 6, with .6 per cent. treatment, were in general similar to ingot 4. In the titanium-treated ingots, the part of the cavity above the bridge appeared (from the smoothness of its surface) to have been due to the collection of gas, while that below the bridge had the appearance of having been formed by shrinkage. The interior condition of ingot 7, made of plain steel, held three minutes in the ladle before pouring, was similar in a general way to the interior condition of ingot 1; that is, there was a large interior cavity in the upper part of the ingot, surrounded with a honeycombing of small holes.

It thus appears that the effect of the treatment of this steel with titanium, used as described, was to cause a solidifying of the metal around the large interior cavity in the upper part of the ingot. The ingots of plain Bessemer steel each contained a large cavity near the top of the ingot, whose appearance indicated it to have been due mostly or entirely to the collection of gas, and in addition, the metal of the upper fifth of

FIG. 1. INGOT 1, PLAIN BESSEMER.

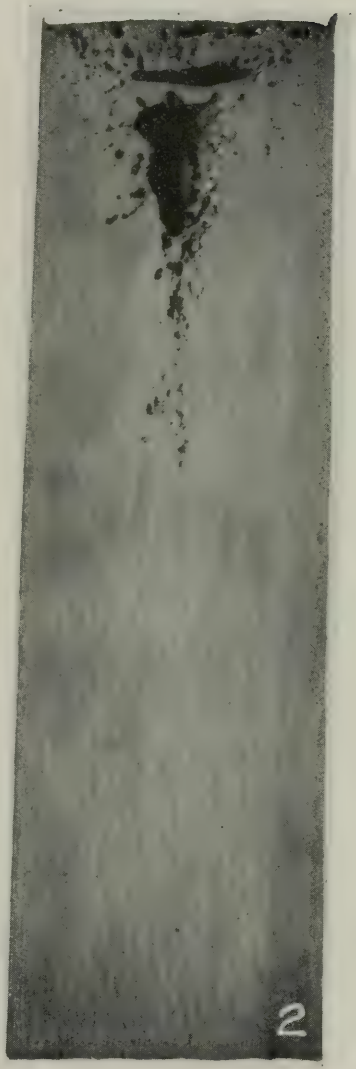

FIG. 2. INGOT 2, TREATED WITH .05 PER CENT. METALLIC TITANIUM.

FIG. 3. INGOT 3, TREATED WITH .1 PER CENT. METALLIC TITANIUM.

FIG. 4. INGOT 4, TREATED WITH .2 PER CENT. METALLIC TITANIUM.

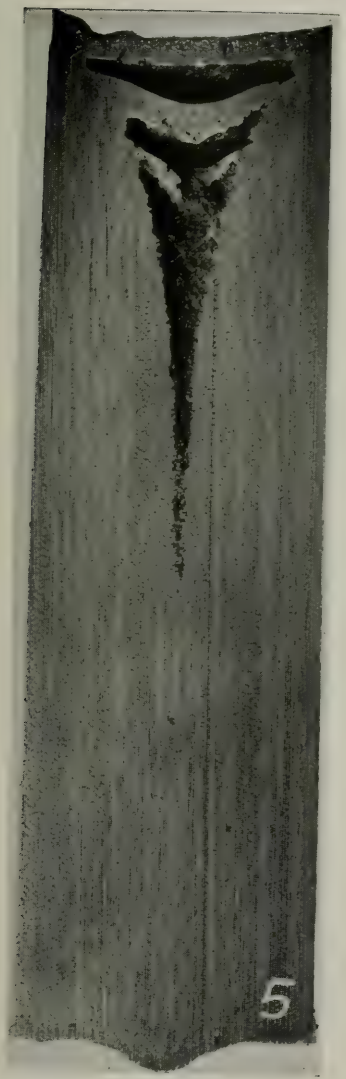

FIG. 5. INGOT 5, TREATED WITH .4 PER CENT. METALLIC TITANIUM.

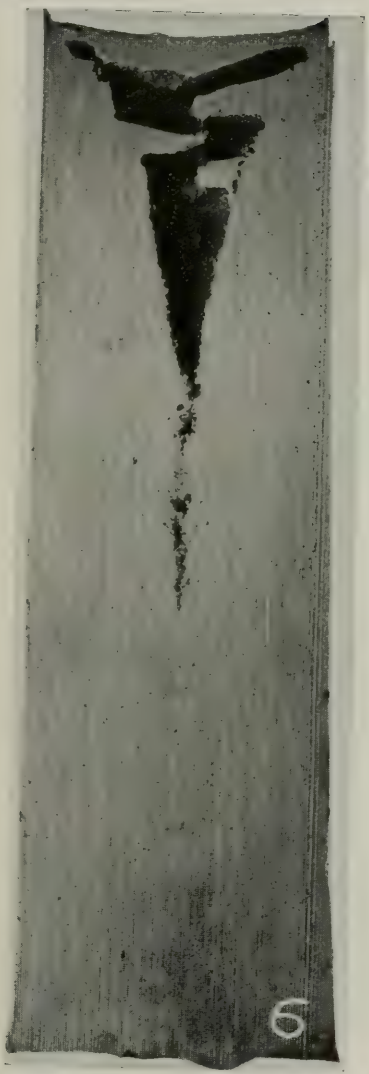

FIG. 6. INGOT 6, TREATED WITH .6 PER CENT. METALLIC TITANIUM.

Fig. 7. Ingot 7, Plain Bessemer, Held in the Ladle 3 Minutes.

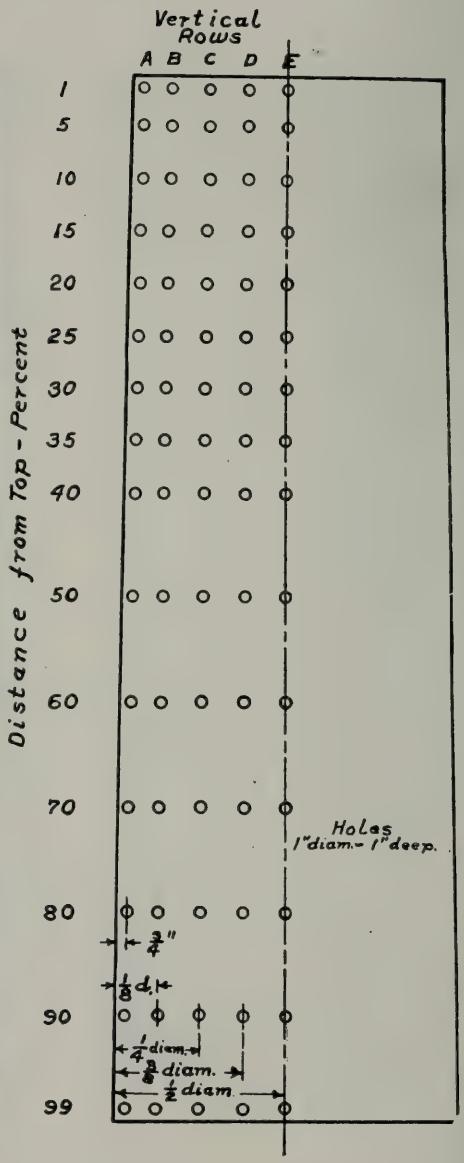

Fig. 8. Drilling Diagram for Rail Ingots.

the ingot was "honeycombed" with small holes. With treatments of .1 per cent. or over of metallic titanium, the ingots each had the large main cavity, but the metal surrounding it was solid, or practically so, but in addition there was a tapering extension of the cavity downward, apparently due to shrinkage of the metal. The two portions of the cavity were separated by a "bridge" which, in some cases, was broken. With .05 per cent. treatment with metallic titanium there was a partial solidifying of the above-mentioned surrounding metal.

ANALYSES OF INGOTS.

A chemical survey was made of each ingot by means of drillings taken as shown in fig. 8, the drillings being taken from the halves of the ingots previously illustrated. It will be noted that there were five vertical rows of drillings from one-half of the section, making a total of 75 samples from each ingot, less the number that could not be obtained due to the cavities in the ingot. On each sample, determinations were made of carbon (by combustion), phosphorus, sulphur, manganese and silicon, and on some of them, of titanium also. These analyses are shown in tables as follows:

Carbon, tables 5 to 11, inclusive.
Phosphorus, tables 12 to 18, inclusive.
Sulphur, tables 19 to 25, inclusive.
Manganese, tables 26 to 32, inclusive.
Silicon, tables 33 to 39, inclusive.
Titanium, table 40.

TABLE 5—CARBON IN INGOT 1—PLAIN STEEL.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.508	.506	.362	.425	.470
5	.396	.457	....	.481	.514
10	.402	.449	.519	....	....
15	.450	.475	.526	....	....
20	.503	.498	.544	.608	....
25	.507	.511	.535	.572	.675
30	.520	.512	.539	.629	.615
35	.509	.510	.529	.570	.628
40	.510	.526	.535	.546	.628
50	.515	.532	.525	.515	.517
60	.505	.500	.525	.503	.490
70	.484	.502	.532	.497	.485
80	.503	.510	.515	.498	.463
90	.498	.515	.507	.497	.488
99	.494	.510	.513	.510	.482

TABLE 6—CARBON IN INGOT 2—.05 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.423	.402	.248	.391	....
5	.460	.482	.492	....	....
10	.455	.446	.496	....	....
15	.507	.479	.487	....	....
20	.505	.495	.527	.595	....
25	.513	.510	.542	.590	.692
30	.508	.515	.565	.564	.583
35	.523	.517	.535	.55	.548
40	.512	.515	.535	.527	.525
50	.510	.514	.542	.495	.495
60	.495	.510	.515	.504	.477
70	.488	.518	.500	.499	.490
80	.500	.513	.490	.495	.507
90	.490	.500	.477	.470	.453
99	.498	.497	.481	.500	.465

TABLE 7—CARBON IN INGOT 3—.1 PER CENT TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.481	.369	....	....	....
5	.507	.496	....	....	....
10	.514	.517	.495	.512	....
15	.519	.513	.530	....	....
20	.507	.539	.572	.585	....
25	.520	.504	.536	.598	....
30	.536	.530	.540	.565	....
35	.509	.510	.582	.585	.509
40	.512	.526	.521	.53	.50
50	.515	.519	.523	.494	.440
60	.527	.535	.537	.482	.524
70	.509	.53	.495	.485	.438
80	.517	.513	.487	.450	.433
90	.523	.520	.484	.512	.464
99	.517	.500	.517	.513	.510

TABLE 8—CARBON IN INGOT 4—.2 PER CENT TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.51	.518	.501	.505	.506
5	.523	.526	....	....	....
10	.534	.512	.50	....	....
15	.523	.53	.535	....	....
20	.508	.524	.542	.562	....
25	.526	.535	.565	.575	....
30	.521	.535	.541	.577	....
35	.534	.513	.542	.550	.498
40	.509	.528	.549	.520	.500
50	.501	.534	.540	.51	.508
60	.522	.515	.551	.508	.459
70	.516	.522	.540	.495	.453
80	.515	.531	.508	.469	.496
90	.518	.518	.507	.505	.474
99	.534	.533	.540	.508	.540

TABLE 9—CARBON IN INGOT 5—.4 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.497	.448	.435	.448	.441
5	.485	.45	....	....	....
10	.473	.462	.418	.462	.414
15	.480	.485	.510	....	....
20	.489	.480	.511	.510	....
25	.503	.481	.526	.529	....
30	.49	.477	.494	.554	....
35	.482	.489	.515	.526	.593
40	.482	.498	.509	.517	.498
50	.498	.485	.508	.505	.485
60	.485	.492	.506	.469	.455
70	.488	.498	.51	.473	.487
80	.479	.512	.485	.454	.437
90	.500	.494	.468	.450	.458
99	.505	.475	.493	.509	.493

TABLE 10—CARBON IN INGOT 6—.6 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.487	.46	.465	.468	.473
5	.468	.465	....	....	....
10	.468	.469	.482	.487	....
15	.468	.473	.478	....	....
20	.470	.503	.478	.507	....
25	.475	.482	.482	.508	....
30	.504	.466	.510	.544	....
35	.502	.458	.492	.518	.446
40	.473	.472	.481	.50	.471
50	.481	.468	.496	.508	.442
60	.468	.509	.496	.431	.404
70	.472	.498	.476	.469	.443
80	.497	.502	.457	.429	.420
90	.485	.478	.434	.430	.410
99	.465	.465	.478	.466	.447

TABLE 11—CARBON IN INGOT 7—PLAIN STEEL, HELD IN LADLE.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.425	.360	.413	.390	.40
5	.456	.465	.403	.407	.475
10	.452	.452	.462	....	....
15	.500	.498	.494	.563	....
20	.494	.515	.515	.615	....
25	.518	.517	.517	.55	....
30	.510	.495	.510	.545	.600
35	.496	.496	.524	.547	.583
40	.501	.486	.533	.521	.516
50	.543	.509	.503	.48	.484
60	.475	.482	.491	.473	.485
70	.475	.505	.475	.483	.457
80	.490	.497	.480	.460	.431
90	.495	.471	.457	.427	.438
99	.500	.487	.475	.503	.510

TABLE 12—PHOSPHORUS IN INGOT 1—PLAIN STEEL.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.082	.080	.065	.068	.052
5	.080	.079	.....	.066	.079
10	.058	.088	.082	....	....
15	.084	.080	.088	....	....
20	.090	.102	.096	.108	....
25	.090	.096	.098	.105	.130
30	.094	.092	.090	.092	.130
35	.081	.093	.089	.097	.099
40	.092	.089	.096	.095	.090
50	.093	.090	.096	.090	.087
60	.088	.092	.096	.088	.086
70	.090	.086	.094	.083	.078
80	.081	.085	.085	.084	.080
90	.086	.090	.088	.087	.081
99	.084	.085	.086	.088	.085

TABLE 13—PHOSPHORUS IN INGOT 2—.05 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.079	.067	.054	.061	....
5	.062	.071	.074	....	....
10	.074	.069	.080	....	....
15	.076	.077	.067	....	....
20	.080	.089	.089	.111	....
25	.089	.090	.094	.116	.159
30	.088	.089	.098	.103	.113
35	.090	.094	.092	.096	.097
40	.092	.094	.092	.096	.097
50	.092	.090	.095	.084	.083
60	.084	.087	.090	.088	.073
70	.084	.087	.093	.076	.074
80	.080	.086	.086	.072	.074
90	.084	.086	.078	.089	.074
99	.084	.084	.083	.084	.080

TABLE 14—PHOSPHORUS IN INGOT 3—.1 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.079	.060	....	....	....
5	.080	.085	....	....	....
10	.087	.079	.080	.079	....
15	.086	.085	.092	....	....
20	.086	.085	.092	.102	....
25	.084	.088	.092	.101	....
30	.087	.086	.090	.094	.086
35	.085	.088	.096	.084	.078
40	.088	.088	.099	.087	.089
50	.091	.090	.089	.087	.085
60	.088	.092	.089	.089	.072
70	.088	.090	.091	.076	.067
80	.086	.086	.088	.070	.068
90	.083	.088	.079	.087	.078
99	.079	.082	.084	.083	.085

TABLE 15—PHOSPHORUS IN INGOT 4—.2 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.060	.085	.080	.046	.074
5	.076	.084	....	....	....
10	.085	.083	.082	....	....
15	.084	.085	.086	....	....
20	.085	.089	.090	.096	....
25	.089	.083	.095	.089	....
30	.085	.079	.085	.090	....
35	.086	.085	.090	.091	.082
40	.082	.084	.084	.082	.082
50	.088	.084	.080	.083	.067
60	.080	.080	.078	.080	.077
70	.086	.087	.089	.081	.076
80	.088	.089	.083	.080	.076
90	.084	.082	.075	.079	.074
99	.081	.080	.083	.085	.080

TABLE 16—PHOSPHORUS IN INGOT 5—.4 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.081	.071	.062	.076	.064
5	.091	.078	....	....	....
10	.088	.085	.077	.065	.070
15	.088	.084	.084	....	....
20	.089	.085	.088	.080	....
25	.079	.081	.091	.087	....
30	.085	.087	.087	.091	....
35	.083	.081	.082	.087	.081
40	.085	.089	.085	.084	.072
50	.083	.090	.088	.086	.080
60	.081	.086	.092	.081	.075
70	.085	.087	.091	.083	.081
80	.087	.083	.070	.070	.068
90	.082	.088	.083	.080	.086
99	.086	.089	.088	.089	.087

TABLE 17—PHOSPHORUS IN INGOT 6—.6 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.080	.078	.079	.080	.079
5	.080	.076	....	....	....
10	.084	.082	.084	.089	....
15	.082	.083	.086	....	....
20	.082	.084	.085	.082	....
25	.084	.086	.084	.087	....
30	.083	.085	.086	.087	....
35	.085	.084	.086	.092	.078
40	.083	.086	.086	.088	.075
50	.085	.086	.089	.086	.070
60	.084	.085	.088	.089	.069
70	.083	.085	.080	.078	.078
80	.084	.086	.077	.069	.070
90	.084	.086	.082	.070	.070
99	.084	.086	.087	.086	.088

TABLE 18—PHOSPHORUS IN INGOT 7—PLAIN STEEL, HELD IN LADLE.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.064	.065	.061	.058	.053
5	.076	.075	.072	.076	.078
10	.078	.075	.080	....	....
15	.088	.088	.080	.108	....
20	.095	.093	.082	.112	....
25	.096	.095	.094	.114	....
30	.094	.097	.093	.112	.136
35	.093	.097	.099	.100	.112
40	.096	.098	.104	.103	.097
50	.094	.103	.104	.094	.095
60	.096	.096	.102	.095	.096
70	.094	.098	.098	.090	.083
80	.093	.098	.096	.087	.081
90	.097	.102	.092	.087	.087
99	.096	.102	.097	.097	.093

TABLE 19—SULPHUR IN INGOT 1—PLAIN STEEL.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.036	.034	.025	.030	.028
5	.026	.030	....	.032	.032
10	.022	.027	.032	....	....
15	.031	.030	.031	....	....
20	.034	.037	.038	.051	....
25	.035	.038	.043	.042	.067
30	.034	.038	.042	.043	.058
35	.038	.042	.042	.043	.049
40	.040	.042	.046	.040	.044
50	.037	.039	.043	.038	.041
60	.037	.039	.040	.039	.036
70	.037	.040	.040	.039	.036
80	.039	.041	.040	.037	.035
90	.040	.040	.037	.036	.036
99	.038	.039	.039	.040	.038

TABLE 20—SULPHUR IN INGOT 2—.05 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.030	.030	.023	.027	....
5	.031	.030	.030	....	....
10	.030	.030	.034	....	....
15	.032	.033	.030	....	....
20	.035	.038	.034	.056	....
25	.037	.038	.040	.050	.087
30	.040	.040	.045	.045	.054
35	.041	.041	.044	.041	.051
40	.038	.040	.044	.040	.047
50	.040	.040	.042	.039	.039
60	.038	.036	.037	.039	.039
70	.040	.042	.044	.040	.033
80	.038	.040	.040	.037	.035
90	.037	.043	.040	.030	.032
99	.030	.029	.033	.033	.034

TABLE 21—SULPHUR IN INGOT 3—.1 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.037	.028	....	....	....
5	.039	.037	....	....	....
10	.038	.040	.038	.036	....
15	.041	.042	.043	.....	....
20	.041	.040	.042	.045	....
25	.039	.042	.042	.054	....
30	.040	.042	.043	.048	.043
35	.039	.050	.040	.044	.031
40	.035	.039	.042	.036	.031
50	.037	.037	.038	.034	.029
60	.041	.038	.040	.035	.032
70	.035	.036	.038	.033	.030
80	.038	.038	.036	.031	.028
90	.033	.040	.036	.034	.034
99	.036	.038	.035	.036	.036

TABLE 22—SULPHUR IN INGOT 4—.2 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.035	.039	.037	.037	.035
5	.037	.038	....	....	....
10	.041	.039	.035	....	....
15	.041	.038	.037	....	....
20	.035	.040	.038	.037	....
25	.039	.039	.038	.039	....
30	.039	.036	.040	.041	.....
35	.038	.037	.040	.040	.039
40	.037	.036	.043	.037	.039
50	.038	.041	.041	.039	.030
60	.040	.042	.040	.037	.032
70	.037	.036	.039	.034	.030
80	.039	.039	.036	.032	.031
90	.036	.036	.034	.033	.032
99	.036	.038	.040	.039	.039

TABLE 23—SULPHUR IN INGOT 5—.4 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.037	.033	.031	.033	.033
5	.040	.034	....	....	....
10	.040	.038	.039	.030	.032
15	.041	.042	.036	....	....
20	.040	.037	.044	.039	....
25	.041	.037	.044	.041	....
30	.040	.041	.043	.045	....
35	.038	.039	.042	.045	.043
40	.041	.040	.044	.043	.033
50	.039	.040	.045	.040	.037
60	.042	.039	.043	.035	.038
70	.040	.041	.046	.039	.037
80	.042	.040	.038	.034	.033
90	.044	.037	.034	.037	.037
99	.039	.040	.041	.040	.036

TABLE 24—SULPHUR IN INGOT 6—.6 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.039	.035	.040	.037	.037
5	.040	.037	....	....	....
10	.036	.042	.035	.039	....
15	.038	.040	.035	....	....
20	.035	.038	.039	.038	....
25	.040	.042	.044	.044	....
30	.042	.043	.044	.046	....
35	.041	.042	.043	.045	.040
40	.039	.042	.044	.044	.038
50	.043	.037	.042	.041	.041
60	.041	.043	.044	.037	.035
70	.037	.036	.040	.036	.038
80	.041	.040	.039	.038	.035
90	.041	.041	.034	.032	.033
99	.038	.037	.036	.037	.042

TABLE 25—SULPHUR IN INGOT 7—PLAIN STEEL, HELD IN LADLE.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.033	.032	.030	.030	.030
5	.035	.038	.035	.035	.041
10	.037	.038	.036	....	....
15	.043	.040	.038	.053	....
20	.046	.045	.037	.059	....
25	.044	.051	.049	.057	....
30	.043	.044	.044	.057	.074
35	.045	.047	.049	.053	.057
40	.046	.046	.050	.050	.049
50	.051	.050	.047	.044	.043
60	.046	.046	.047	.047	.042
70	.046	.046	.046	.042	.041
80	.047	.047	.044	.040	.038
90	.046	.047	.047	.044	.041
99	.044	.045	.046	.045	.045

TABLE 26—MANGANESE IN INGOT 1—PLAIN STEEL.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.93	.97	.93	.87	.95
5	.95	.97	....	.99	.95
10	.93	.95	.94	....	....
15	.95	.97	.93	....	....
20	.95	.97	.95	.98	....
25	.95	.95	.97	.97	.99
30	.97	.97	.97	.97	.99
35	.93	.97	.97	.99	.98
40	.96	.94	.96	.98	.96
50	.97	.97	.97	.93	.95
60	.97	.96	.96	.94	.93
70	.92	.95	.95	.92	.93
80	.92	.95	.94	.94	.94
90	.90	.92	.91	.93	.93
99	.91	.94	.97	.95	.93

TABLE 27—MANGANESE IN INGOT 2—.05 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.86	.86	.89	.94	....
5	.88	.94	.90	....	....
10	.90	.90	.87	....	....
15	.94	.86	.88	....	....
20	.89	.90	.90	.93	....
25	.89	.90	.91	.93	.94
30	.92	.91	.90	.89	.90
35	.90	.89	.90	.89	.92
40	.91	.90	.90	.87	.90
50	.91	.93	.94	.90	.91
60	.90	.91	.93	.90	.89
70	.90	.88	.87	.87	.89
80	.90	.88	.85	.89	.87
90	.89	.90	.90	.89	.86
99	.92	.90	.92	.88	.88

TABLE 28—MANGANESE IN INGOT 3—.1 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.92	.88	....	....	....
5	.93	.93	....	....	....
10	.93	.92	.87	.88	....
15	.89	.90	.91	....	....
20	.88	.90	.92	.92	....
25	.87	.88	.92	.90	....
30	.87	.85	.87	.89	.91
35	.92	.92	.94	.93	.91
40	.89	.90	.92	.91	.91
50	.90	.94	.93	.90	.87
60	.90	.94	.93	.90	.93
70	.94	.93	.91	.93	.96
80	.89	.88	.92	.86	.85
90	.87	.95	.91	.91	.90
99	.92	.90	.87	.87	.87

TABLE 29—MANGANESE IN INGOT—.2 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.90	.96	.90	.96	.97
5	.93	.96	....	....	....
10	.98	.97	.98	....	....
15	.96	.93	.95	....	....
20	.95	.99	.99	1.01	....
25	.93	.97	.99	1.00	....
30	.95	.94	.94	.97	....
35	.97	.94	.93	.93	.95
40	.91	.95	.96	.95	.94
50	.97	.95	.97	.96	.94
60	.95	.96	.96	.95	.95
70	.92	.92	.93	.94	.90
80	.92	.94	.93	.92	.90
90	.93	.93	.92	.94	.91
99	.94	.94	.92	.90	.90

TABLE 30—MANGANESE IN INGOT 5—.4 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.84	.80	.80	.83	.83
5	.84	.81	....	....	....
10	.83	.82	.81	.79	.75
15	.81	.83	.83	....	....
20	.83	.82	.83	.82	....
25	.87	.84	.85	.83	....
30	.83	.80	.83	.81	....
35	.82	.86	.84	.85	.85
40	.85	.83	.85	.83	.82
50	.85	.84	.85	.83	.83
60	.80	.85	.85	.81	.85
70	.80	.82	.82	.80	.80
80	.81	.82	.83	.80	.80
90	.82	.83	.80	.80	.81
99	.85	.83	.84	.84	.82

TABLE 31—MANGANESE IN INGOT 6—.6 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.84	.85	.83	.87	.85
5	.85	.88	....	....	....
10	.83	.83	.87	.88	....
15	.86	.88	.91	....	....
20	.85	.85	.84	.89	....
25	.83	.87	.86	.88	....
30	.84	.83	.87	.86	....
35	.83	.85	.85	.85	.83
40	.84	.82	.83	.83	.83
50	.85	.87	.87	.87	.83
60	.84	.87	.85	.81	.81
70	.84	.84	.84	.87	.83
80	.87	.86	.85	.84	.86
90	.86	.87	.84	.82	.82
99	.85	.86	.88	.86	.85

TABLE 32—MANGANESE IN INGOT 7—PLAIN STEEL, HELD IN LADLE.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.96	.99	.98	.97	.97
5	.97	.97	.97	.99	.97
10	.96	.96	.95	....	....
15	.96	.94	.94	.94	....
20	.96	.99	.97	1.01	....
25	.97	.98	.98	.99	....
30	.98	.96	1.03	1.03	1.01
35	.98	.99	.99	.99	.97
40	.97	.98	.97	.97	.96
50	.99	.97	.96	.97	.96
60	.96	.98	.98	.96	.96
70	.98	.97	.98	.96	.94
80	.96	.98	.96	.96	.95
90	.98	.97	.96	.96	1.03
99	.98	.99	.96	.96	.96

TABLE 33—SILICON IN INGOT 1—PLAIN STEEL.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.108	.125	.118	.125	.153
5	.096	.114	....	.107	.126
10	.109	.114	.116	....	....
15	.110	.120	.113	....	....
20	.119	.118	.113	.121	....
25	.124	.122	.125	.128	.112
30	.115	.120	.117	.128	.102
35	.106	.121	.112	.125	.115
40	.127	.115	.103	.112	.112
50	.117	.115	.110	.111	.115
60	.115	.099	.115	.112	.122
70	.116	.116	.110	.119	.115
80	.115	.117	.112	.111	.111
90	.110	.111	.113	.120	.121
99	.115	.115	.103	.106	.105

TABLE 34—SILICON IN INGOT 2—.05 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.122	.112	.127	.128	....
5	.116	.123	.125	....	....
10	.127	.117	.120	....	....
15	.125	.116	.114	....	....
20	.115	.119	.115	.111	....
25	.111	.110	.107	.108	.127
30	.117	.120	.115	.115	.113
35	.115	.119	.111	.110	.112
40	.119	.113	.117	.104	.103
50	.122	.107	.100	.111	.111
60	.110	.120	.113	.100	.122
70	.122	.119	.113	.108	.123
80	.120	.117	.122	.125	.120
90	.122	.120	.123	.119	.122
99	.115	.119	.114	.114	.119

TABLE 35—SILICON IN INGOT 3—.1 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.132	.135	....	....	....
5	.121	.124	....	....	....
10	.115	.108	.112	.108	....
15	.114	.112	.112	....	....
20	.116	.117	.112	.116	....
25	.115	.116	.107	.112	....
30	.116	.106	.108	.110	.116
35	.115	.112	.118	.116	.107
40	.113	.117	.105	.105	.103
50	.108	.109	.112	.109	.107
60	.115	.114	.115	.112	.114
70	.105	.110	.114	.113	.111
80	.107	.109	.111	.108	.110
90	.103	.105	.107	.106	.107
99	.109	.108	.110	.107	.111

TABLE 36—SILICON IN INGOT 4—.2 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.119	.127	.119	.131	.122
5	.115	.125	....	....	....
10	.122	.121	.121	....	....
15	.113	.114	.119	....	....
20	.117	.117	.115	.122	....
25	.119	.121	.117	.116	....
30	.115	.115	.112	.107	....
35	.115	.119	.119	.117	.113
40	.110	.114	.105	.111	.118
50	.117	.111	.115	.106	.117
60	.115	.110	.109	.111	.112
70	.119	.112	.119	.117	.114
80	.118	.115	.116	.111	.111
90	.116	.113	.112	.114	.111
90	.113	.111	.110	.113	.111

TABLE 37—SILICON IN INGOT 5—.4 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.122	.129	.129	.119	.122
5	.103	.110	....	....	....
10	.110	.115	.113	.116	.110
15	.113	.116	.113	....	....
20	.110	.113	.103	.110	....
25	.110	.119	.113	.113	....
30	.119	.113	.116	.116	....
35	.120	.123	.121	.115	.119
40	.112	.115	.115	.119	.109
50	.115	.112	.112	.109	.106
60	.109	.106	.106	.103	.109
70	.112	.109	.112	.110	.113
80	.109	.110	.110	.105	.109
90	.109	.111	.105	.110	.109
99	.110	.111	.112	.111	.111

TABLE 38—SILICON IN INGOT 6—.6 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.118	.102	.110	.118	.094
5	.127	.107	....	....	....
10	.113	.112	.117	.109	....
15	.116	.108	.099	....	....
20	.108	.113	.097	.122	....
25	.105	.115	.094	.077	....
30	.107	.100	.114	.081	....
35	.107	.107	.121	.103	.095
40	.103	.108	.114	.107	.111
50	.108	.112	.107	.114	.102
60	.100	.113	.099	.104	.111
70	.100	.122	.102	.110	.110
80	.094	.102	.115	.114	.119
90	.114	.110	.116	.118	.109
99	.101	.100	.113	.114	.110

TABLE 39—SILICON IN INGOT 7—PLAIN STEEL, HELD IN LADLE.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.138	.155	.148	.155	.152
5	.138	.140	.146	.143	.134
10	.138	.124	.129	....	....
15	.138	.125	.129	.115	....
20	.129	.141	.138	.138	....
25	.141	.129	.133	.132	....
30	.135	.135	.133	.132	.125
35	.124	.139	.135	.128	.118
40	.132	.131	.135	.129	.132
50	.125	.138	.135	.135	.116
60	.138	.132	.129	.132	.118
70	.135	.117	.122	.124	.135
80	.135	.129	.129	.141	.140
90	.135	.129	.138	.147	.122
99	.118	.118	.132	.132	.138

TABLE 40—TITANIUM IN INGOT 4—.2 PER CENT. TREATMENT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.192	.288	.225	.285	.285
5	.023	.023	....	....	....
10	.030	.021	.018	....	....
15	.021	.018	.018	....	....
20	.024	.018	.021	.018	....
25	.021	.020	.019	.016	....
30	.018	.018	.021	.017	....
35	.021	.021	.018	.018	.017
40	.019	.021	.018	.019	.018
50	.025	.018	.015	.015	.015
60	.022	.017	.018	.018	.022
70	.022	.021	.018	.026	.025
80	.021	.020	.018	.023	.021
90	.021	.020	.023	.027	.027
99	.021	.018	.018	.017	.019

Probably the five samples from the bottom of the ingot represent fairly closely the average steel in the ingot, and I give in table 41 the average of these five samples from each ingot, and for comparison the results on the heat sample taken when pouring the steel.

TABLE 41—AVERAGE STEEL IN INGOTS.

	C.	P.	S.	Mn.	Si.
Ingot 1, plain steel.....	.502	.086	.039	.94	.109
heat sample.....	.498	.087	.039	.92	.103
Ingot 2, .05% treatment.	.488	.083	(.037)	.90	.116
heat sample.....	.491	.087	.035	.86	.105
Ingot 3, .1% treatment..	.511	.083	.036	.89	.109
heat sample.....	.504	.088	.038	.92	.098
Ingot 4, .2% treatment..	.531	.082	.038	.92	.112
heat sample.....	.501	.088	.037	.92	.105
Ingot 5, .4% treatment...	.495	.088	.039	.84	.111
heat sample.....	.495	.092	.040	.84	.107
Ingot 6, .6% treatment...	.464	.086	.038	.86	.108
heat sample.....	.478	.090	.039	.89	.100
Ingot 7, plain steel.....	.495	.097	.045	.97	.128
heat sample.....	.482	.098	.042	1.04	.128

The five results on sulphur from the bottom of ingot 2, seem by comparison with the other sulphur determinations from this ingot, to be evidently too low, and in this case the average of the six results from the wall of the lower half of the ingot is given as representing the average sulphur of the ingot. In most cases there is good agreement between the heat analysis and the average in the ingot obtained as described.

At any given distance from the top of the ingot the extreme variations in composition are in general shown by the axis and the walls of the ingot, and to show conveniently the changes from the top to the bottom of the ingot, figures 9, 10 and 11 are given, showing the plotted results for carbon, phosphorus and sulphur, respectively, each figure showing the results on one element for each of the seven ingots. The distance from the top of the ingot, in per cent. of the height, is shown horizontally, and the amount of the element is shown vertically. Where samples could not be obtained from the axis on account of cavities, the results from row D were, in general, taken as representing the axis. Lines are also drawn on each diagram representing the average of the element in the ingot. It will be noticed that the axis at the top of the ingot shows negative segregation of the three elements, but the amounts increase rapidly and then show positive segregation, reaching maxima at, in general, about 25 or 30 per cent. of the height from the top of the ingot. *With titanium treatments of .1 per cent. or over it will be noted that the segregation of carbon, phosphorus and sulphur was much less than in the plain Bessemer steel, or in the steel treated with only .05 per cent. metallic titanium.* About half-way down the ingot the elements at the axis again reach their average amounts, and continue to decrease, showing some negative segregation in the lower half of the ingot. The amounts again rise close to the bottom and reach their average amounts. The extent of the negative segregation at the axis in the lower part of the ingot seems not to have been influenced materially by the titanium treatment.

The walls of the ingots show negative segregation of the three elements at the top, but the amounts rise until the average amount is reached, after which they remain, roughly, uniform to the bottom of the ingot. With titanium treatments of .1 per cent. or over this negative segregation in the wall was in most cases only slight, but was considerable in the plain steel and in the steel with .05 per cent. treatment, and in these the average content was, in general, reached at about 15 or 20 per cent. of the height from the top of the ingot.

The maximum amounts of positive segregation found at the axis of the various ingots, and the percents of increase above the average contents of the respective ingots are shown in table 42.

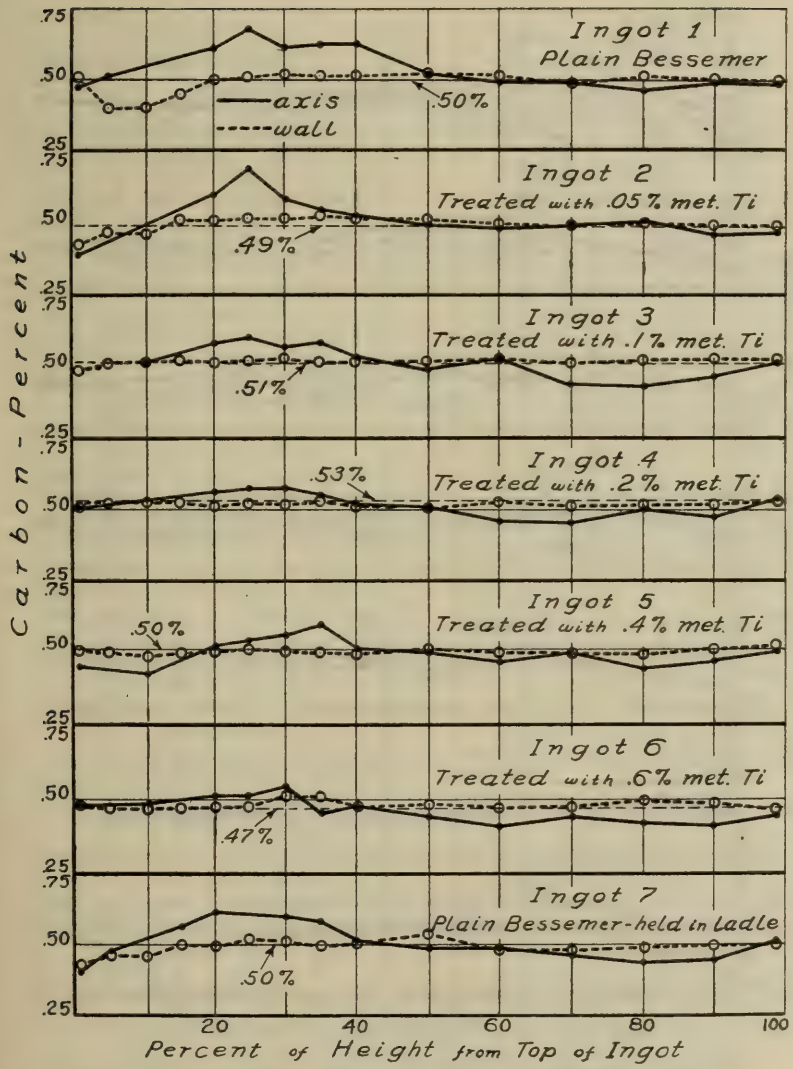

FIG. 9. CARBON DIAGRAMS OF THE AXES AND WALLS OF THE SEVEN INGOTS.

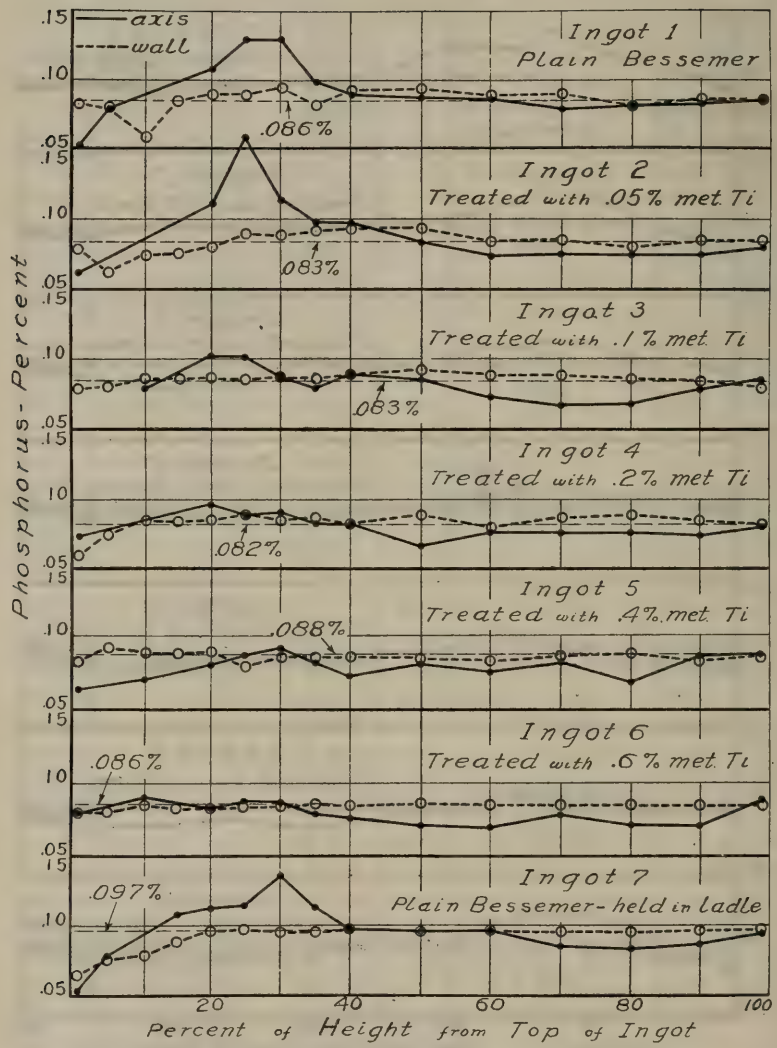

FIG. 10. PHOSPHORUS DIAGRAMS OF THE AXES AND WALLS OF THE SEVEN INGOTS.

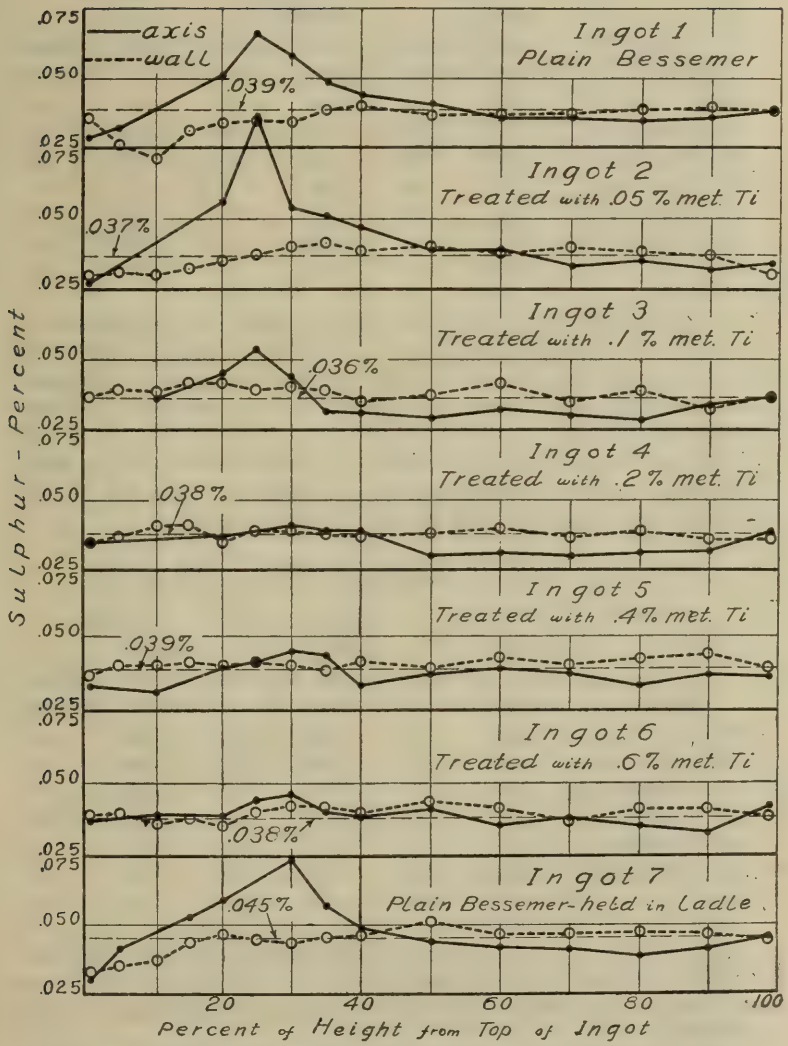

FIG. 11. SULPHUR DIAGRAMS OF THE AXES AND WALLS OF THE SEVEN INGOTS.

TABLE 42—POSITIVE SEGREGATION AT AXES OF INGOTS.

Ingot number.	Carbon. Maximum amount.	Carbon. Increase. per cent.	Phosphorus. Maximum amount.	Phosphorus. Increase. per cent.	Sulphur. Maximum amount.	Sulphur. Increase per cent.
1 plain	.675	33	.130	51	.067	72
2 .05% treatment..	.692	42	.159	92	.067	135
3 .1% treatment..	.598	17	.102	23	.054	50
4 .2% treatment..	.577	9	.096	17	.041	8
5 .4% treatment..	.593	20	.091	3	.045	15
6 .6% treatment..	.544	17	.089	3	.046	21
7 plain	.615	24	.136	40	.074	64

It will be noticed that the greatest segregation or concentration of carbon, phosphorus and sulphur was found in the ingot treated with .05 per cent. titanium, the next greatest in the two ingots of plain steel, and considerably less in the ingots made of steel treated with .1 per cent. or more of titanium.

The maximum amounts of negative segregation found in the walls of the various ingots and the percents. of decrease below the average contents of the respective ingots are shown in table 43.

TABLE 43—NEGATIVE SEGREGATION IN WALLS OF INGOTS.

Ingot number.	Carbon. Minimum amount.	Carbon. Decrease. per cent.	Phosphorus. Minimum amount.	Phosphorus. Decrease. per cent.	Sulphur. Minimum amount.	Sulphur. Decrease. per cent.
1 plain	.396	21	.058	33	.022	44
2 .05% treatment..	.423	13	.062	25	.030	19
3 .1% treatment..	.481	6	.079	5	.033	8
4 .2% treatment..	.501	6	.060	24	.035	8
5 .4% treatment..	.473	5	.079	10	.037	5
6 .6% treatment..	.468	0	.080	7	.035	8
7 plain	.423	15	.064	34	.033	27

This table shows the negative segregation in the walls to have been greatest in the plain steel, next greatest in the steel treated with .05 per cent. titanium, and slight in the steel treated with .1 per cent. or more of titanium.

Fig. 12 is given to show in the seven ingots the separation of the phosphorus into regions of different concentrations, and the same diagrams may be taken to represent the distribution of the carbon and sulphur. Five concentrations of phosphorus were selected, as shown in table 44, and the approximate amounts of carbon and sulphur represented by these regions are also shown in the same table.

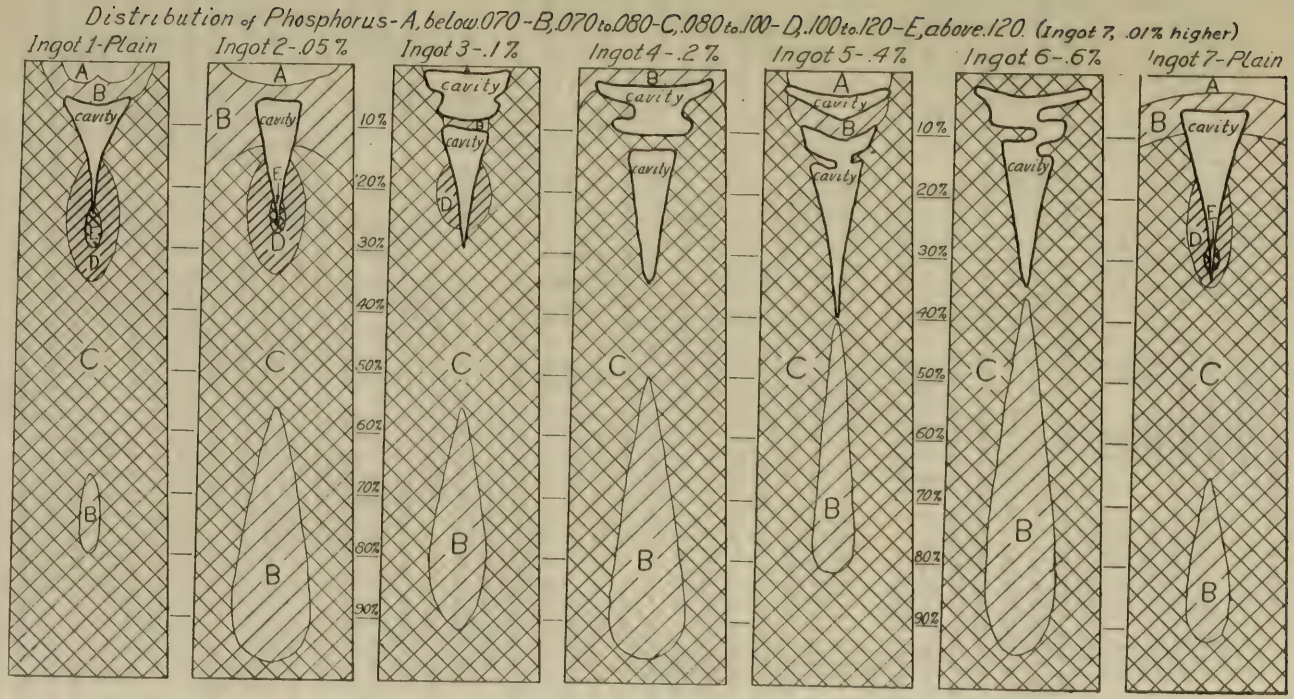

FIG. 12. DISTRIBUTION OF PHOSPHORUS IN THE SEVEN INGOTS.

TABLE 44—REGIONS OF VARIOUS CONCENTRATIONS.

	Phosphorus.	Carbon.	Sulphur.
A	Below .070	Below .45	Below .030
B	.070 to .080	.45 to .48	.030 to .035
C	.080 to .100	.48 to .53	.035 to .043
D	.100 to .120	.53 to .60	.043 to .055
E	Above .120	Above .60	Above .055

In the case of ingot 7, the phosphorus and sulphur were higher than in the other ingots, and ranges of phosphorus were taken as .010 per cent. and of sulphur as .005 per cent. higher than shown in the table. The various regions were not sharply defined, as shown on the diagrams, and there were differences in composition even in the first six ingots, but the diagrams show, in a general way, the distribution of the segregating elements. Region C represents steel of about average composition as poured.

Ingot 1 of plain steel, ingot 2 of steel treated with .05 per cent. titanium, and ingot 7 of plain steel held three minutes in the ladle before pouring, contained the greatest positive segregation in the upper and interior part of the ingot. In ingot 3, with .1 per cent. treatment, the segregation was much milder, and ingots 4, 5 and 6, with larger amounts of treatment, there was no prominent concentration of the segregating elements. The lower half of the ingot showed more or less negative segregation in all the ingots, and rather more in those of treated steel than in those of plain steel. *These diagrams indicate that the carbon, phosphorus and sulphur tend to separate from the steel of the lower and interior part of the ingot in both plain and titanium-treated Bessemer steel, but with treatments of .1 per cent. or over with metallic titanium, these elements remain more evenly distributed in the upper part of the ingot than in plain steel.*

An examination of the tables shows that manganese segregated only a little, and silicon segregated little, or not any.

Titanium was determined in all the samples from ingot 4 with .2 per cent. treatment, and the analyses showed a fairly even distribution of this element throughout the ingot except right at the top. The average amount in this ingot, as determined by taking the average of the five samples from the bottom of the ingot, was .019 per cent. The various samples throughout the ingot showed about this amount except that the top row of samples showed titanium varying from .192 per cent. to .288 per cent. Whether these latter samples contained the titanium in metallic form or as oxide, as suggested by their location, was not determined. It is also interesting to note, as shown by table 7, containing the results of the ladle tests, that with treatments of .05 and .1 per cent. titanium, the steel contained only traces of titanium, and with treatments of .2, .4 and .6 per cent., the steel contained only a little over .02 per cent. titanium. I am unable to say whether the alloy failed to dissolve with these larger treatments or whether it dissolved and the titanium was then oxidized by the slag and thus entered the slag as oxide.

TESTS MADE OF RAILS.

The entire rail-bar of each of the ingots used for rails was used for drop tests, tensile tests and cross bending tests of the base, and was divided into units of one-third rail length, or 11 ft. each. From each 11 ft., 1 ft. was cut for tensile test and cross bending test of the base, then 5 ft. for drop test with the head in tension, and the other 5-ft. piece was used for drop test with the base in tension. Nine pieces were taken from each rail, as shown in table 45.

TABLE 45—TESTS FROM EACH RAIL.

No. 1—1 ft. Tensile tests and base test.
No. 2—5 ft. Drop test, head tension.
No. 3—5 ft. Drop test, base tension.
No. 4—1 ft. Tensile tests and base test.
No. 5—5 ft. Drop test, head tension.
No. 6—5 ft. Drop test, base tension.
No. 7—1 ft. Tensile tests and base test.
No. 8—5 ft. Drop test, head tension.
No. 9—5 ft. Drop test, base tension.

The distance of each test piece from the top of the ingot, expressed in lbs. and in per cent. of weight, is shown in tables 46 to 52, incl. This distance is figured to the middle of the test piece.

TABLE 46—TEST PIECES OF RAIL-BAR 1—DISTANCE FROM TOP END.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
1 A 1	269	5.7	1 B 1	1466	30.9	1 C 1	2610	55.0	1 D 1	3754	79.0
2	369	7.8	2	1566	33.0	2	2710	57.1	2	3854	81.2
3	536	11.3	3	1733	36.6	3	2877	60.5	3	4021	84.7
4	636	13.4	4	1833	38.7	4	2977	62.6	4	4121	86.8
5	736	15.5	5	1933	40.8	5	3077	64.7	5	4221	88.9
6	903	19.0	6	2100	44.2	6	3244	68.3	6	4388	92.4
7	1003	21.1	7	2200	46.3	7	3344	70.4	7	4488	94.5
8	1103	23.2	8	2300	48.4	8	3444	72.5	8	4588	96.6
9	1270	26.8	9	2467	52.0	9	3611	76.0	9	.....	.....

TABLE 47—TEST PIECES OF RAIL-BAR 2—DISTANCE FROM TOP END.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
2 A 1	136	2.9	2 B 1	1302	27.7	2 C 1	2422	51.6	2 D 1	3542	75.3
2	236	5.1	2	1402	29.8	2	2522	53.7	2	3642	77.5
3	403	8.6	3	1569	33.4	3	2689	57.2	3	3809	81.0
4	503	10.7	4	1669	35.5	4	2789	59.3	4	3909	83.1
5	603	12.8	5	1769	37.6	5	2889	61.4	5	4009	85.3
6	770	16.4	6	1936	41.1	6	3056	64.9	6	4176	88.8
7	870	18.5	7	2036	43.2	7	3156	67.0	7	4276	90.9
8	970	20.6	8	2136	45.3	8	3256	69.2	8	4376	93.0
9	1137	24.2	9	2303	46.8	9	3423	72.8	9	4543	96.5

TABLE 48—TEST PIECES OF RAIL-BAR 3—DISTANCE FROM TOP END.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
3 A 1	174	3.7	3 B 1	1337	28.3	3 C 1	2457	52.0	3 D 1	3581	76.0
2	274	5.8	2	1437	30.4	2	2557	54.1	2	3681	78.1
3	441	9.3	3	1604	34.0	3	2724	57.7	3	3848	81.6
4	541	11.4	4	1704	36.1	4	2824	59.9	4	3948	83.7
5	641	13.6	5	1804	38.2	5	2924	62.0	5	4048	85.8
6	808	17.1	6	1971	41.8	6	3091	65.5	6	4215	89.4
7	908	19.2	7	2071	43.9	7	3191	67.6	7	4315	91.5
8	1008	21.4	8	2171	46.0	8	3291	69.7	8	4415	93.6
9	1175	24.9	9	2338	49.5	9	3458	73.2	9	4582	97.1

TABLE 49—TEST PIECES OF RAIL-BAR 4—DISTANCE FROM TOP END.

Test piece	Lbsl	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
4 A 1	146	2.9	4 B 1	1331	26.9	4 C 1	2483	50.2	4 D 1	3634	73.5
2	246	5.0	2	1431	28.9	2	2583	52.2	2	3734	75.5
3	413	8.3	3	1598	32.3	3	2750	55.5	3	3901	78.9
4	513	10.4	4	1698	34.3	4	2850	57.6	4	4001	80.9
5	613	12.4	5	1798	36.3	5	2950	59.6	5	4101	82.9
6	780	15.8	6	1965	39.7	6	3117	63.0	6	4268	86.3
7	880	17.8	7	2065	41.7	7	3217	65.0	7	4368	88.3
8	980	19.8	8	2165	43.8	8	3317	67.0	8	4468	90.3
9	1147	23.2	9	2332	47.1	9	3484	70.5	9	4635	93.7

TABLE 50—TEST PIECES OF RAIL-BAR 5—DISTANCE FROM TOP END.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
5 A 1	142	3.0	5 B 1	1320	27.7	5 C 1	2444	51.3	5 D 1	3570	75.0
2	242	5.1	2	1420	29.8	2	2544	53.4	2	3670	77.1
3	409	8.6	3	1587	33.3	3	2711	56.9	3	3837	80.6
4	509	10.7	4	1687	35.4	4	2811	59.0	4	3937	82.7
5	609	12.8	5	1787	37.5	5	2911	61.1	5	4037	84.8
6	776	16.3	6	1954	41.0	6	3078	64.6	6	4204	88.2
7	876	18.4	7	2054	43.1	7	3178	66.7	7	4304	90.3
8	976	20.5	8	2154	45.2	8	3278	68.8	8	4404	92.4
9	1143	24.0	9	2321	48.7	9	3445	72.4	9	4571	95.9

TABLE 51—TEST PIECES OF RAIL-BAR 6—DISTANCE FROM TOP END.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
6 A 1	137	2.9	6 B 1	1333	27.9	6 C 1	2467	51.7	6 D 1	3601	75.4
2	237	5.0	2	1433	30.0	2	2567	53.8	2	3701	77.5
3	404	8.5	3	1600	33.5	3	2734	57.2	3	3868	81.0
4	504	10.5	4	1700	35.6	4	2834	59.3	4	3968	83.0
5	604	12.6	5	1800	37.7	5	2934	61.4	5	4068	85.1
6	771	16.1	6	1967	41.2	6	3101	64.9	6	4235	88.6
7	871	18.2	7	2067	43.3	7	3201	67.0	7	4335	90.7
8	971	20.3	8	2167	45.4	8	3301	69.1	8	4435	92.8
9	1138	23.8	9	2334	47.9	9	3468	72.6	9	4602	96.3

TABLE 52—TEST PIECES OF RAIL-BAR 7—DISTANCE FROM TOP END.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
7 A 1	107	2.3	7 B 1	1303	27.6	7 C 1	2406	50.9	7 D 1	3510	74.3
2	207	4.4	2	1403	29.7	2	2506	53.0	2	3610	76.4
3	374	7.9	3	1570	33.2	3	2673	56.6	3	3777	79.9
4	474	10.0	4	1670	35.3	4	2773	58.7	4	3877	82.0
5	574	12.1	5	1770	37.4	5	2873	60.8	5	3977	84.1
6	741	15.7	6	1937	41.0	6	3040	64.3	6	4144	87.7
7	841	17.8	7	2037	43.1	7	3140	66.4	7	4244	89.8
8	941	19.9	8	2137	45.2	8	3240	68.6	8	4344	91.9
9	1108	23.4	9	2304	48.7	9	3407	72.1	9	4511	95.4

DROP TESTS.

Six drop tests were made of each rail, three with the head in tension and three with the base in tension. The tup was 2,000 lbs., the height of drop was 20 ft., the centers of the supports were 3 ft. apart, and the anvil was the standard spring supported anvil of 20,000 lbs. The striking faces of the tup and the bearing surfaces of the supports had radii of 5 inches. The deflection or set was measured in two ways: first, the distance between a 3-ft. straight edge and the part of the rail where struck by the tup, including the local indentation caused by the tup, and second, the bend of the side that was below as tested was determined in a distance of three ft. This measurement eliminated the local indentation caused by the tup, although the comparatively slight indentations by the supports were included. The deflection gage used was the one shown in Proc. Am. Ry. Engrg. & M. W. Assoc., 1911, Vol. 12, part 2, page 531. Gage marks one inch apart were put lengthwise on the side in tension about the middle of the test piece for a distance of 6 inches, and the length of the space which stretched most at failure was determined and taken as a measure of the ductility of the rail. The results of the drop tests are shown in tables 53 to 59, inclusive, showing the test number, the distance from the top of the ingot in per cent. of the weight, whether the head or the base was in tension, the set after the first blow, the number of blows that it took to break the rail and the per cent. of stretch of the inch that stretched most at failure.

TABLE 53—DROP TESTS, RAIL-BAR I—PLAIN BESSEMER STEEL.

Test Number	Per cent. from top of ingot	Head or base in tension	Set—1st blow		No. of blows	Elongation per cent.
			Top	Bottom		
1 A 2	7.8	Head	1.82	1.64	2	12
1 A 5	15.5	"	1.70	1.55	2	13
1 A 8	23.2	"	.....	.....	1	2
1 B 2	33.0	"	.....	.....	1	7
1 B 5	40.8	"	1.74	1.58	3	34
1 B 8	48.4	"	1.71	1.52	4	27
1 C 2	57.1	"	1.69	1.52	5	28
1 C 5	64.7	"	1.73	1.53	4	33
1 C 8	72.5	"	1.80	1.63	5	28
1 D 2	81.2	"	1.74	1.60	5	51
1 D 5	88.9	"	1.79	1.60	5	40
1 D 8	96.6	"	(1.57)	(1.48)	4	31
Average			1.747	1.574	3.7	25.5
1 A 3	11.3	Base	1.71	1.59	3	14
1 A 6	19.0	"	1.67	1.56	3	14
1 A 9	26.8	"	1.70	1.58	5	25
1 B 3	36.6	"	1.76	1.62	4	23
1 B 6	44.2	"	1.72	1.60	6	29
1 B 9	52.0	"	1.72	1.59	6	..... *
1 C 3	60.5	"	1.75	1.63	5	24
1 C 6	68.3	"	1.71	1.59	5	24
1 C 9	76.0	"	1.71	1.57	6	43
1 D 3	84.7	"	1.76	1.62	4	22
1 D 6	92.4	"	1.70	1.57	6	32
1 D 9	.....	No test piece	.....	.....	.....	.....
Average			1.719	1.593	4.8	25.0
General Average			1.733	.584	4.3	25.3

*Remarks: In test 1 B 9, die of tup moved and elongation not obtained.

TABLE 54—DROP TESTS, RAIL-BAR 2—TREATED WITH .05% TITANIUM.

Test Number	Per cent. from top of ingot	Head or base in tenslon	Set—1st blow		No. of blows	Elongation per cent.
			Top	Bottom		
2 A 2	5.1	Head	1.88	1.67	3	25
2 A 5	12.8	"	1.81	1.64	3	25
2 A 8	20.6	"	1.79	1.60	5	42
2 B 2	29.8	"	1.77	1.59	5	35
2 B 5	37.6	"	1.79	1.63	4	43
2 B 8	45.3	"	1.84	1.66	5	32
2 C 2	53.7	"	1.79	1.63	5	24
2 C 5	61.4	"	1.86	1.67	4	41
2 C 8	69.2	"	1.86	1.67	4	37
2 D 2	77.5	"	1.84	1.67	5	33
2 D 5	85.3	"	1.89	1.71	4	22*
2 D 8	93.0	"	1.88	1.66	4	22
Average			1.833	1.650	4.3	31.8
2 A 3	8.6	Base	1.80	1.67	4	27
2 A 6	16.4	"	1.75	1.53	4	24
2 A 9	24.2	"	1.79	1.66	5	32
2 B 3	33.4	"	1.75	1.64	7	30
2 B 6	41.1	"	1.78	1.66	6	27
2 B 9	46.8	"	1.81	1.68	5	28
2 C 3	57.2	"	1.81	1.67	6	33
2 C 6	64.9	"	1.79	1.66	5	33
2 C 9	72.8	"	1.82	1.68	7	33
2 D 3	81.0	"	1.82	1.68	5	33
2 D 6	88.8	"	1.86	1.73	6	33
2 D 9	96.5	"	1.81	1.69	4	26
Average			1.799	1.663	5.3	29.9
General Average			1.816	1.657	4.8	30.9

*Remarks: Test 2 D 5, base split and flange broken. Head not broken and its ductility not exhausted.

TABLE 55—DROP TESTS, RAIL-BAR 3—TREATED WITH .1% TITANIUM.

Test Number	Per cent. from top of ingot	Head or base in tenslon	Set—1st blow		No. of blows	Elongation per cent.
			Top	Bottom		
3 A 2	5.8	Head	1.79	1.60	4	30*
3 A 5	13.6	"	1.74	1.57	2	15
3 A 8	21.4	"	1.76	1.59	5	33
3 B 2	30.4	"	1.73	1.56	4	36
3 B 5	38.2	"	1.76	1.58	4	30
3 B 8	46.0	"	1.76	1.58	5	38
3 C 2	54.1	"	1.79	1.61	5	39
3 C 5	62.0	"	1.80	1.63	5	41
3 C 8	69.7	"	1.86	1.64	4	27
3 D 2	78.1	"	1.77	1.58	4	34
3 D 5	85.8	"	1.81	1.63	5	44
3 D 8	93.6	"	1.78	1.60	5	34
Average			1.779	1.598	4.3	33.4
3 A 3	9.3	Base	1.72	1.60	5	29*
3 A 6	17.1	"	1.63	1.59	4	19
3 A 9	24.9	"	1.70	1.55	7	34
3 B 3	34.0	"	1.72	1.60	6	31
3 B 6	41.8	"	1.70	1.59	6	32
3 B 9	49.5	"	1.78	1.65	6	38
3 C 3	57.7	"	1.76	1.62	6	32
3 C 6	65.5	"	1.76	1.63	6	27
3 C 9	73.2	"	1.78	1.65	5	27
3 D 3	81.6	"	1.80	1.66	5	30
3 D 6	89.4	"	1.75	1.61	2	8
3 D 9	97.1	"	.....	.....	(1)	.....
Average			1.736	1.614	5.3	27.9
General Average			1.758	1.606	4.8	30.7

*Remarks: Web of test piece: A 2, laminated from head to base. Web of test piece: A 3 laminated from about middle of height to base. In testing 3 D 9, die of tup slipped on 1st blow.

TABLE 56—DROP TESTS, RAIL-BAR 4—TREATED WITH .2% TITANIUM.

Test Number	Per cent. from top of ingot	Head or base in tension	Set—1st blow		No. of blows	Elongation per cent.
			Top	Bottom		
4 A 2	5.0	Head	.....	.....	1	9*
4 A 5	12.4	"	1.69	1.50	4	26
4 A 8	19.8	"	1.65	1.48	2	15
4 B 2	28.9	"	1.67	1.51	3	22
4 B 5	36.3	"	1.65	1.48	5	49
4 B 8	43.8	"	1.65	1.50	4	25
4 C 2	52.2	"	1.70	1.53	5	27
4 C 5	59.6	"	1.71	1.54	4	29
4 C 8	67.0	"	1.73	1.56	6	30
4 D 2	75.5	"	1.69	1.51	6	40
4 D 5	82.9	"	1.70	1.53	5	32
4 D 8	90.3	"	1.77	1.57	3	25
Average			1.692	1.519	4.0	27.4
4 A 3	8.3	Base	1.65	1.53	5	28*
4 A 6	15.8	"	1.64	1.51	7	35
4 A 9	23.2	"	1.65	1.52	5	31
4 B 3	32.3	"	1.65	1.52	4	27
4 B 6	39.7	"	.....	.....	6	29
4 B 9	47.1	"	1.71	1.58	6	31
4 C 3	55.5	"	1.69	1.56	6	25
4 C 6	63.0	"	1.66	1.55	3	13
4 C 9	70.5	"	1.63	1.52	6	30
4 D 3	78.9	"	1.70	1.56	5	32
4 D 6	86.3	"	1.72	1.59	4	25
4 D 9	93.7	"	1.76	1.61	5	30
Average			1.678	1.550	5 2	28.0
General Average			1.685	1.535	4.6	27.7

*Remarks: Test piece 4 A 2 showed a ¼ inch horizontal flaw near top of head. Test piece 4 A 3 showed a 1-inch vertical lamination about middle of web.

TABLE 57—DROP TESTS, RAIL-BAR 5—TREATED WITH .4% TITANIUM.

Test piece	Per cent. from top of ingot	Head or base in tension	Set—1st blow		No. of blows	Elongation per cent.
			Top	Bottom		
5 A 2	5.1	Head	1.82	1.63	4	24*
5 A 5	12.8	"	1.80	1.62	3	26
5 A 8	20.5	"	1.78	1.59	2	11
5 B 2	29.8	"	1.82	1.65	4	39
5 B 5	37.5	"	1.84	1.64	.....	.....
5 B 8	45.2	"	1.73	1.57	5	31
5 C 2	53.4	"	1.80	1.63	5	32
5 C 5	61.1	"	1.76	1.60	5	34
5 C 8	68.8	"	1.79	1.61	4	24
5 D 2	77.1	"	1.82	1.63	4	30
5 D 5	84.8	"	1.83	1.64	3	24
5 D 8	92.4	"	1.85	1.64	5	30
Average			1.803	1.621	4.0	27.7
5 A 3	8.6	Base	1.71	1.57	5	27
5 A 6	16.3	"	1.73	1.60	4	27*
5 A 9	24.0	"	1.73	1.63	4	26
5 B 3	33.3	"	1.70	1.58	.....	.....
5 B 6	41.0	"	1.67	1.54	6	29
5 B 9	48.7	"	1.77	1.65	4	29
5 C 3	56.9	"	1.78	1.65	5	32
5 C 6	64.6	"	1.74	1.63	6	31
5 C 9	72.4	"	1.79	1.64	7	32
5 D 3	80.6	"	1.80	1.66	6	30
5 D 6	88.2	"	1.80	1.67	5	24
5 D 9	95.9	"	1.83	1.69	5	32
Average			1.754	1.626	5.2	29 0
General Average			1.779	1.624	4.6	28 4

*Remarks: Test piece 5 A 2 had about a ½ inch inverted U-shaped flaw in the web. Test piece 5 A 6 had a 1½-inch vertical lamination in the web, from the bottom of the head downward.

TABLE 58—DROP TESTS, RAIL-BAR 6—TREATED WITH .6% TITANIUM.

Test piece	Per cent. from top of ingot	Head or base in tension	Set—1st blow		No. of blows	Elongation per cent.
			Top	Bottom		
6 A 2	5.0	Head	1.98	1.76	6	30
6 A 5	12.6	"	1.83	1.64	5	28
6 A 8	20.3	"	1.84	1.65	4	22
6 B 2	30.0	"	1.78	1.58	5	35
6 B 5	37.7	"	1.80	1.64	6	28
6 B 8	45.4	"	1.78	1.60	6	47
6 C 2	53.8	"	1.77	1.60	5	30
6 C 5	61.4	"	1.78	1.59	5	30
6 C 8	69.1	"	1.87	1.68	5	27
6 D 2	77.5	"	1.91	1.71	5	42
6 D 5	85.1	"	1.96	1.76	4	37
6 D 8	92.8	"	2.07	1.85	4	36
Average			1.864	1.672	5.2	32.7
6 A 3	8.5	Base	1.82	1.69	4	30*
6 A 6	16.1	"	1.78	1.64	5	31
6 A 9	23.8	"	1.80	1.66	5	32
6 B 3	33.5	"	1.80	1.66	5	36
6 B 6	41.2	"	1.78	1.65	4	30
6 B 9	47.9	"	1.77	1.62	5	27
6 C 3	57.2	"	1.78	1.64	6	33
6 C 6	64.9	"	1.78	1.63	4	25
6 C 9	72.6	"	1.86	1.69	5	30
6 D 3	81.0	"	1.87	1.74	4	31
6 D 6	88.6	"	1.97	1.81	5	32
6 D 9	96.3	"	1.94	1.80	7	33
Average			1.829	1.686	5.0	30.8
General Average			1.847	1.679	5.1	31.8

*Remarks: Test piece 6 A 3 showed a 2-inch vertical lamination in middle of web.

TABLE 59—DROP TESTS, RAIL-BAR 7—PLAIN BESSEMER, HELD IN LADLE.

Test piece	Per cent. from top of ingot	Head or base in tension	Set—1st blow		No. of blows	Elongation per cent.
			Top	Bottom		
7 A 2	4.4	Head	.....	.....	1	4*
7 A 5	12.1	"	1.73	1.56	2	11
7 A 8	19.9	"	1.65	1.50	2	9
7 B 2	29.7	"	1.80	1.65	4	37
7 B 5	37.4	"	1.74	1.56	5	34
7 B 8	45.2	"	1.76	1.57	2	12
7 C 2	53.0	"	1.80	1.62	4	40
7 C 5	60.8	"	1.71	1.54	4	20
7 C 8	68.6	"	1.71	1.52	5	30
7 D 2	76.4	"	1.81	1.61	5	25
7 D 5	84.1	"	1.80	1.61	5	26
7 D 8	91.9	"	1.67	1.49	5	29
Average			1.744	1.566	3.7	23.1
7 A 3	7.9	Base	1.81	1.69	2	12
7 A 6	15.7	"	1.60	1.47	5	29
7 A 9	23.4	"	1.62	1.51	3	12
7 B 3	33.2	"	1.63	1.50	5	30
7 B 6	41.0	"	1.61	1.49	5	24
7 B 9	48.7	"	1.64	1.53	5	28
7 C 3	56.6	"	1.63	1.49	6	23
7 C 6	64.3	"	1.63	1.50	3	14
7 C 9	72.1	"	1.68	1.56	6	27
7 D 3	79.9	"	1.66	1.51	6	30
7 D 6	87.7	"	.....	.....	1	1
7 D 9	95.4	"	1.76	1.61	2	7
Average			1.661	1.533	4.1	19.8
General Average			1.703	1.550	3.9	21.5

*Test piece 7 A 2 showed several vertical laminations in web distributed from head to base.

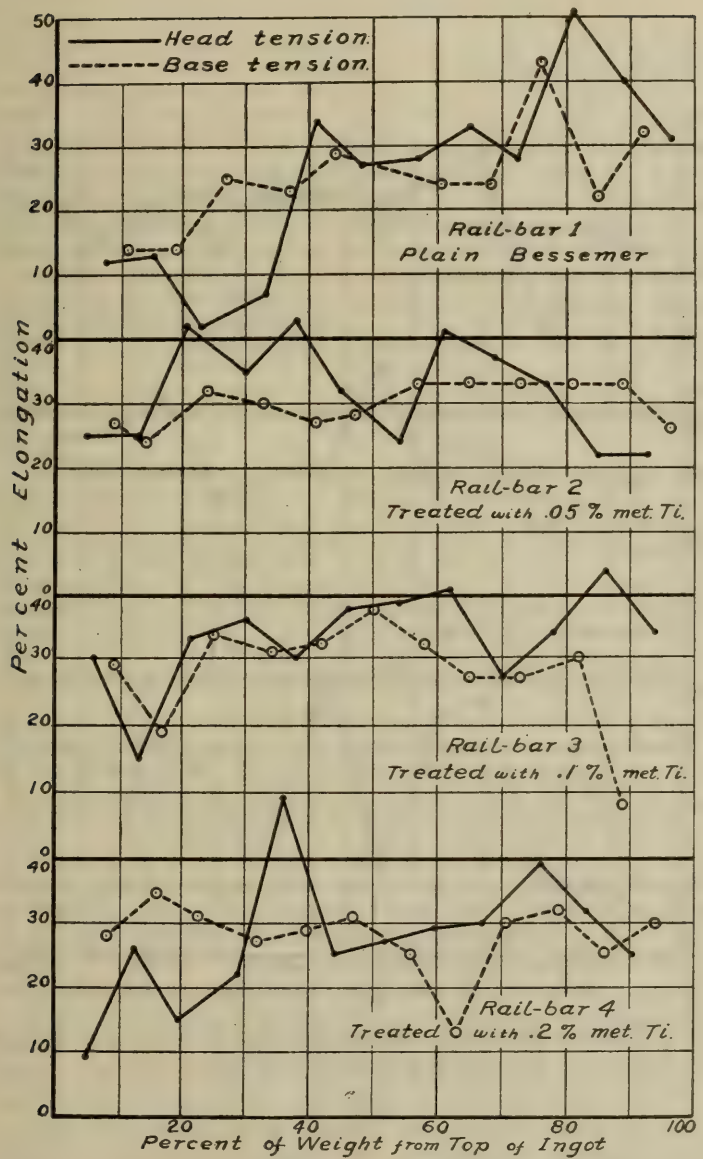

FIG. 13. ELONGATION IN DROP TEST OF RAIL-BARS 1, 2, 3 AND 4, AS RELATED TO DISTANCE FROM TOP OF INGOT.

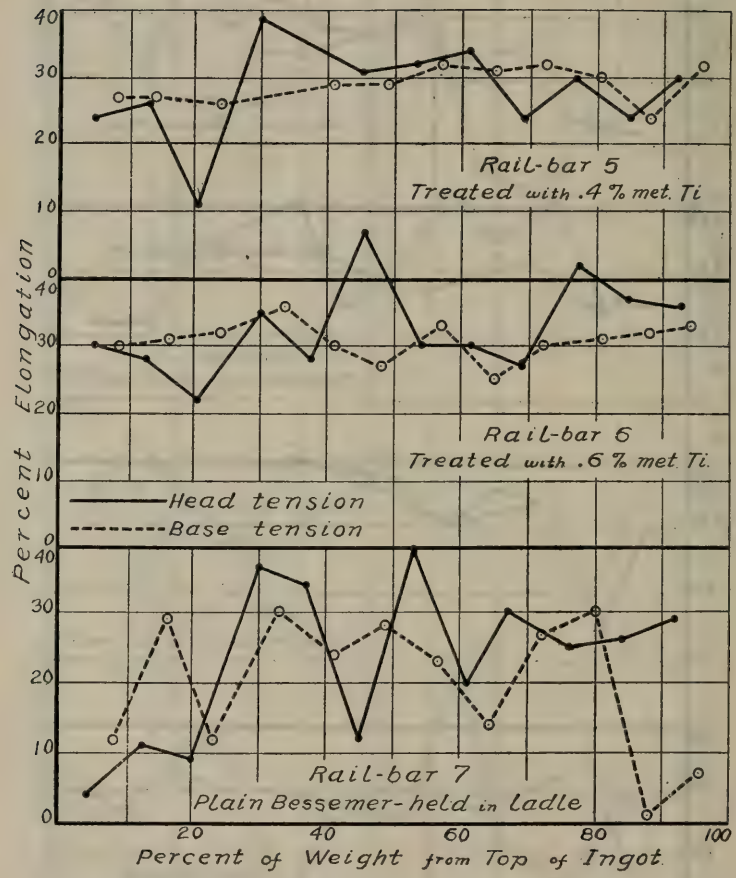

FIG. 14—ELONGATION IN DROP TEST OF RAIL-BARS 5, 6 AND 7 AS RELATED TO DISTANCE FROM TOP OF INGOT.

DUCTILITY IN DROP TESTS.

As stated above, the inch space which stretched most at failure in the drop test was taken as the measure of ductility of the piece of rail tested. The elongation results for rail-bars 1 to 4 inclusive are plotted in fig. 13 and those for rail-bars 5, 6 and 7 are plotted in fig. 14, the elongation being represented vertically, and the distance from the top end of the ingot in per cent. of the total weight being represented horizontally. For each rail-bar, one curve shows the results with the head in tension and another curve shows the results with the base in tension. Considering rail-bar 1 made of plain Bessemer steel, it will be noted that the elongation with base tension increased in a general way downward of the ingot from about 14 per cent. to about 30 per cent. With head tension the elongation at first decreased, dropping to a very few per cent. about one-fourth way down the ingot, and then increased in a general way for the rest of the way down the ingot, finally averaging over 30 per cent.

Rail-bar 2 made of metal treated with .05 per cent. of metallic titanium showed about the same elongation in the different parts of the bar, that is, the elongation was about the same in the A, or top rail, as in the lower rails of the ingot. The lowest elongation obtained in this bar was 22 per cent. and the average of all the results was 30.9 per cent. Rail-bar 3, with .1 per cent. treatment, showed somewhat similar results, except that at about 15 per cent. down the elongation was somewhat lower, and also one test of a piece from the D rail gave only 8 per cent. elongation. Rail-bar 4, with .2 per cent. treatment, showed very good elongation with the base in tension, except for one result from the C rail. which got down to 13 per cent. With the head in tension the A rail did not show as well as the rest of the bar, one result getting down to 9 per cent. Rail-bar 5, with .4 per cent. treatment, and rail-bar 6, with .6 per cent treatment, with the base in tension, showed good ductility along the whole bar, averaging about 30 per cent. elongation and about the same in the A rail as in the rest of the bar. With the head in tension, rail-bar 5 gave one result of 11 per cent. elongation at about 20 per cent. from the top, but the other results were 24 per cent. or over. Rail-bar 6, with the head in tension, gave good elongation along the whole bar, although not as high in the A rail as in the rest of the bar. It should be remembered in this connection that the steel from the .05 per cent. and the .1 per cent. treatments showed only traces of titanium, and the steel from the .2, .4 and .6 per cent. treatments showed only .021, .024 and .021 per cent. respectively of titanium.

Rail-bar 7, made of plain Bessemer steel, held in the ladle 3 minutes, the same as the titanium-treated heats in addition to the 2½ minutes in the converter, gave very irregular results. With the head in tension, the three results from the A rail varied from 4 to 11 per cent. elongation. The rest of the bar gave good elongation, except one piece from the lower

end of the B rail, which gave 12 per cent. With the base in tension, two of the pieces from the D rail gave low elongations, one of them 1 per cent. and the other 7 per cent., but these low results seem to be abnormal in this lower part of the bar.

INFLUENCE OF TITANIUM ON DUCTILITY IN DROP TEST.

In order to compare the effect of the different treatments as shown by the elongations in the drop test, table 60 is given, showing the average elongation of the whole rail-bar, of the A rails and of the B, C and D rails, and also of the results with head tension and with base tension for each of the above conditions.

TABLE 60—ELONGATIONS IN DROP TEST.

	Rail-bar Number.						
	1	2	3	4	5	6	7
Titanium Treatment.	None.	.05%	.1%	.2%	.4%	.6%	None.
Whole rail-bar							
Head tension....	25.5	31.8	33.4	27.4	27.7	32.7	23.1
Base tension....	25.0	29.9	27.9	28.0	29.0	30.8	19.8
Average	25.3	30.9	30.7	27.7	28.4	31.8	21.5
A-rails							
Head tension....	9.0	30.7	26.1	16.7	20.3	26.7	8.0
Base tension.....	17.7	27.7	27.3	31.3	26.7	31.0	17.7
Average	13.3	29.2	26.7	24.0	23.5	28.8	12.8
B, C and D rails							
Head tension	31.0	32.1	35.9	31.0	30.5	34.7	28.1
Base tension.....	28.1	30.7	28.1	26.9	29.9	30.8	20.5
Average	29.6	31.4	32.0	29.0	30.2	32.8	24.3

These results are shown graphically in fig. 15, the per cent. of treatment with the titanium alloy, figured as metallic titanium, being shown horizontally and the per cent. elongation being shown vertically. The points showing the results for plain Bessemer steel are each the average of the corresponding results for rail-bars 1 and 7. Considering first the average base tension results of the whole rail-bars, it will be noted that starting with plain steel, the elongation averaged about 22%, with the addition of .05% titanium the elongation averaged almost 30%, with .1% treatment it dropped again to about 28% and then increased again slightly with treatments of increased amounts of titanium. With the head in tension, there was an increase in elongation with the addition of .05% titanium, and a further increase with the addition of .1% titanium. With the addition of .2 per cent. titanium there was a drop in the elongation down to near what it was in the plain steel. With additions of .4 and .6 per cent. titanium, there was again an increase of elongation.

A study of the elongation curves of the individual rail-bars indicates that the differences in the averages for the bars were due mostly to differences in the upper part of the bar, or A rail, and in order to show this better separate curves are also given in fig. 15 showing the average elongations of the A rails, and the average elongations of the rest of the rail-bars, or the B, C and D rails, as related to amount of titanium treatment. The A rail referred to here is the rail after about 4 or 5 per cent. by weight has been removed from what was the top part of the ingot, although in regular mill practice considerably more is ordinarily cut off.

FIG. 15. ELONGATION IN DROP TEST AS RELATED TO AMOUNT OF TITANIUM TREATMENT.

Considering first the average base tension results of the A rails, it will be noted that the elongation was roughly the same for the different amounts of titanium treatment and about one-fourth more than the elongation of the plain Bessemer rails. For plain steel it averaged about 23 per cent. and for the treated steel about 29 per cent. With the head in tension, the average elongation of the A rail increased very considerably with the addition of .05 per cent. titanium, but decreased some

with the addition of .1 per cent. and still more with .2 per cent addition. With .4 per cent. and .6 per cent. treatments, the elongations again increased. With plain steel the average of the two A rails was 8.5 per cent., with .05 per cent. treatment the average of the three results from the A rail was 30.7 per cent. and with the .2 per cent. treatment it was 16.7 per cent.

Considering now the average of the results from the rest of the rail-bar, or B, C and D rails, it should be remarked that the lower end of bar 7 of plain steel, with base in tension, gave two very low and evidently abnormal results, which brought the average as plotted lower than it probably should be. Making this allowance, it appears that the elongation was about the same for all the rail-bars, averaging a little below 30 per cent. with the base in tension and a little over 30 per cent. with the head in tension.

It thus appears that the addition of titanium in the manufacture of Bessemer steel improved the ductility, as measured in the drop test, of rail made from the upper fourth by weight of the ingot, and more when tested with the head in tension than with the base in tension. The treatment had little, if any, influence on the ductility of rail made from the rest of the ingot. The influence of titanium on the ductility seemed not to be greatly dependent on the amount used within the range of amounts used in this work of .05 per cent. to .6 per cent. metallic titanium and introduced by throwing the alloy into the pouring ladle. The best results were obtained with the .05 per cent. and .1 per cent. treatment. It should be noted that with these latter treatments the amounts of titanium found in the steel, as determined by the ladle test, were traces, and with treatments of .2 per cent. or more about .02 per cent. titanium, or a little over, was found in the steel.

An important consideration in this connection is probably the minimum ductility shown by each of the rail-bars, and table 61 is given, showing the minimum ductility found both with head tension and with base tension, and also showing the distance of the middle of the piece tested by per cent. of weight from the top of the ingot.

TABLE 61—MINIMUM DUCTILITY IN DROP TEST.

		Head Tension.		Base Tension.	
Rail-bar.	Titanium treatment.	Elongation per cent.	Per cent. from top.	Elongation per cent.	Per cent. from top.
1	None.	2	23.2	14	11.3 and 19.0
2	.05%	22	85.3 and 93.0	24	16.4
3	.1%	15	13.6	8	89.4
4	.2%	9	5.0	13	63.0
5	.4%	11	20.5	24	88.2
6	.6%	22	20.3	25	64.9
7	None.	4	4.4	1	87.7

INTERNAL DEFECTS.

Table 62 is given, showing the internal defects such as laminations and "pipes" found in the fractured surfaces of the pieces that were drop-tested.

TABLE 62—INTERNAL DEFECTS IN RAILS

Rail-bar.	Titanium treatment.	Per cent. from top.	Defect.
1	None.		None found.
2	.05%		None found.
3	.1%	5.8	Web laminated from head to base.
		9.3	Web laminated from about middle of height to base.
4	.2%	5.0	A ¼-inch horizontal flaw near top of head.
		8.3	A 1-inch vertical lamination about middle of web.
5	.4%	5.1	A ½-inch inverted U-shaped flaw in web.
		16.3	A 1½-inch vertical lamination in web, from bottom of head downward.
6	.6%	8.5	A 2-inch vertical lamination in middle of web.
7	None.	4.4	Several vertical laminations in web distributed from head to base.

The "per cent. from top" represents the distance by weight from the top of the ingot. It will be noted that no internal structural flaws were found in rail-bar 1 of plain steel or in rail-bar 2 with .05 per cent. treatment. With .1 per cent. treatment a large internal flaw was found at 9.3 per cent. down; with .2 per cent. treatment, at 8.3 per cent. down; with .4 per cent., at 16.3 per cent. down; with .6 per cent. treatment, at 8.5 per cent. down; and in rail-bar 7 with no treatment internal flaws were found at 4.4 per cent. down. These flaws, of course, extended down distances somewhat greater than shown by the figures given, say probably two or three per cent. more. *According to these results, therefore, rails made of steel treated with titanium in amounts of .1 per cent or more of metallic titanium, contained large internal flaws at distances varying from about 10 to 18 per cent. by weight from the top of the ingot. With plain Bessemer steel or with .05 per cent. treatment, internal flaws were absent or were close to the top.*

DEFLECTION.

The average deflections for each rail-bar with the head in tension and with the base in tension, and the average of both are collected together for convenient comparison in table 63. These are the permanent sets under the first blow at 20 ft., of the side on top when tested.

TABLE 63—AVERAGE SETS, 1ST BLOW FROM 20 FT.

Rail-bar	Titanium treatment.	Head tension.	Base tension.	Average.	Carbon.
1	None.	1.747	1.719	1.733	.502
2	.05%	1.833	1.799	1.816	.488
3	.1%	1.779	1.736	1.758	.511
4	.2%	1.692	1.678	1.685	.531
5	.4%	1.803	1.754	1.779	.495
6	.6%	1.864	1.829	1.847	.464
7	None.	1.744	1.661	1.703	.495

It appears from these figures that although there were differences in deflection between the various rail-bars, they seem not to have any special relationship to the amount of titanium treatment.

The deflection results for each of the rail-bars are plotted in fig. 16, the distance from the top of the ingot being plotted horizontally, and the deflection vertically. With most of the bars the deflection was about the same along the length of the bar, but seems to have been a minimum at about 30 or 40 per cent. from the top of the ingot; that is, the rail was a little the stiffest in this region. The deflection with the head in tension averaged about .03 or .04 inch more than with the base in tension.

TENSILE TESTS.

Three tensile tests were made from each third of a rail length along each of the rail-bars, one sample from the upper corner of the head, marked "a," one from the interior of the head near the web, marked "b," and one from the flange, marked "c," all as shown in fig. 17. The samples from the corner of the head and the flange were taken from the "under" side, or side that was below in rolling. The test pieces were 10 in. long turned to ½ in. diameter for a gage length of 2 in., and the ends were ¾ in. diameter. The tests were made in a 200,000 lbs. Riehle test machine, and the pieces were held with wedge grips. The yield point was determined by means of a Capp's multiplying dividers. The results of the tests are shown in tables 64 to 70 inclusive.

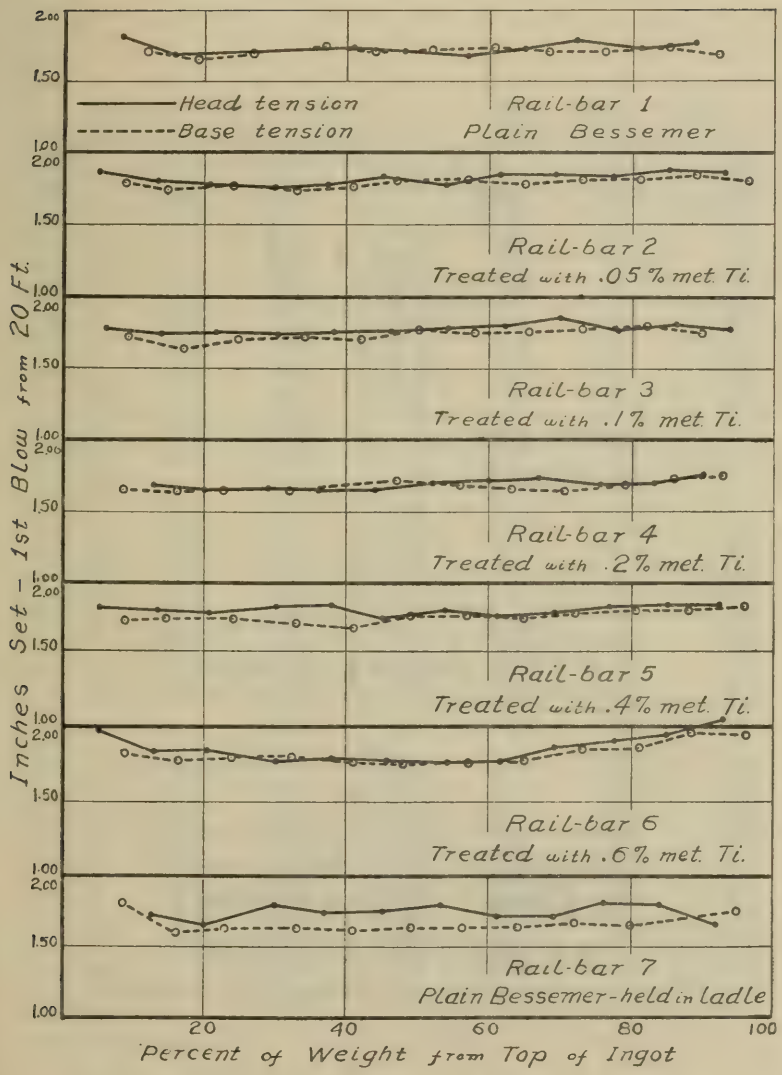

FIG. 16. DEFLECTION IN DROP TEST AS RELATED TO DISTANCE FROM TOP OF INGOT.

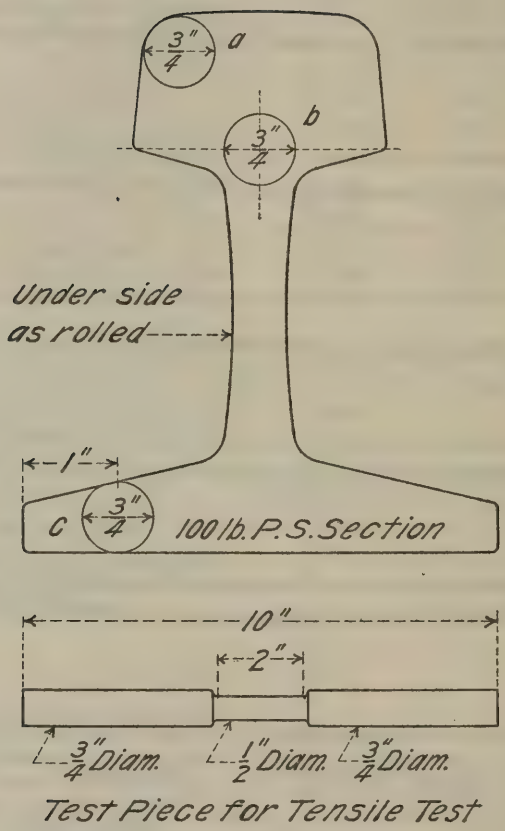

FIG. 17. TENSILE SPECIMEN AND METHOD OF TAKING.

TABLE 64—TENSILE TESTS, RAIL-BAR I—PLAIN BESSEMER STEEL.

Test Number	Per cent. from top of ingot	Yld. Pnt. lbs. per sq. in.	Tens. Str. lbs. per sq. in.	Ratio per cent.	Elong. per cent. in 2 in.	Reduct. of area per cent.
1 A, 1 a	5.7	60,680	103,100	58.8	23.5	45.5
4 a	13.4	62,620	112,900	55.5	2.5	7.1
7 a	21.1	60,720	116,700	52.1	18.0	28.9
1 B, 1 a	30.9	62,970	116,300	54.0	19.0	29.8
4 a	38.7	64,450	115,600	55.7	18.5	36.5
7 a	46.3	60,100	114,800	52.4	18.5	34.1
1 C, 1 a	55.0	64,000	115,700	55.3	20.0	35.7
4 a	62.6	59,070	115,400	51.2	18.5	35.8
7 a	70.4	62,610	116,200	53.8	19.5	35.5
1 D, 1 a	79.0	63,850	117,100	54.5	19.5	37.1
4 a	86.8	60,820	115,900	52.5	19.0	36.6
7 a	94.5	63,740	114,000	55.8	20.5	38.9
1 a	86.8	60,820				
4 a	86.8	60,820	115,900	52.5	19.0	36.6
7 a	94.5	63,740	114,000	55.8	20.5	38.9
Average		62,135	114,475	54.3	18.0	33.4
1 A, 1 b	5.7	60,760	114,100	53.2	19.5	34.7
4 b	13.4	63,050	120,600	52.3	4.5	3.6
7 b	21.1	62,000	120,700	51.4	8.0	7.8
1 B, 1 b	30.9	62,260	97,030	....	3.5	29.5
4 b	38.7	62,680	117,100	53.5	16.0	31.0
7 b	46.3	57,080	115,100	50.5	18.5	33.1
1 C, 1 b	55.0	59,880	115,400	51.8	19.5	36.0
4 b	62.6	55,040	111,500	49.4	19.0	33.7
7 b	70.4	54,480	110,800	49.2	19.5	37.0
1 D, 1 b	79.0	60,700	111,000	54.7	20.0	41.0
4 b	86.8	56,140	107,600	52.2	19.5	36.6
7 b	94.5	61,040	116,000	52.6	20.5	34.9
Average		59,592	113,077	51.8	15.6	29.9
1 A, 1 c.	5.7	63,840	110,200	57.8	22.0	40.8
4 c	13.4	60,170	115,400	52.1	17.0	20.4
7 c	21.1	64,810	118,000	54.8	18.5	27.0
1 B, 1 c	30.9	63,350	116,500	54.3	16.5	34.5
4 c	38.7	62,690	116,700	53.8	17.5	37.4
7 c	46.3	59,480	115,700	51.5	19.0	36.5
1 C, 1 c	55.0	67,740	117,900	57.5	19.0	36.6
4 c	62.6	58,160	116,400	50.0	19.0	34.0
7 c	70.4	67,380	116,800	57.7	19.5	36.7
1 D, 1 c	79.0	69,190	118,700	62.5	20.0	40.2
4 c	86.8	62,150	116,600	53.3	18.0	36.8
7 c	94.5	67,740	115,200	58.8	22.0	40.9
Average		63,891	116,175	55.3	19.0	35.1
General Average		61,873	114,575	53.9	17.5	32.8

TABLE 65—TENSILE TESTS, RAIL-BAR 2—TREATED WITH .05% TITANIUM.

Test Number	Per cent. from top of ingot	Yld. Pnt. lbs. per sq. in.	Tens. Str. lbs. per sq. in.	Ratio per cent.	Elong. per cent. in 2 in.	Reduct. of area per cent.
2 A, 1 a	2.9	61,030	107,200	57.0	17.0	25.7
4 a	10.7	59,640	113,900	52.4	17.0	28.9
7 a	18.5	55,530	114,000	48.7	18.5	34.7
2 B, 1 a	27.7	58,420	115,000	50.7	18.5	34.4
4 a	35.5	59,060	114,100	51.7	20.5	37.5
7 a	43.2	58,370	113,900	51.3	18.0	36.3
2 C, 1 a	51.6	61,460	114,200	53.8	18.5	34.0
4 a	59.3	57,510	113,500	50.7	19.0	32.7
7 a	67.0	62,320	114,100	54.6	19.5	35.1
2 D, 1 a	75.3	59,020	114,600	51.6	18.5	29.5
4 a	83.1	57,890	112,100	51.7	19.0	34.3
7 a	90.9	60,360	109,700	55.1	19.5	38.2
Average		59,217	113,025	52.4	18.6	33.4
2 A, 1 b	2.9	61,090	111,600	54.8	19.5	35.2
4 b	10.7	64,960	125,400	51.8	13.5	22.6
7 b	18.5	65,750	130,600	50.4	12.5	19.2
2 B, 1 b	27.7	63,480	124,100	51.1	14.5	23.9
4 b	35.5	60,040	117,400	51.1	16.5	27.2
7 b	43.2	58,150	113,700	51.2	18.0	31.3
2 C, 1 b	51.6	55,460	111,100	50.0	18.5	34.7
4 b	59.3	54,770	109,200	50.1	18.5	32.8
7 b	67.0	65,540	110,800	59.1	18.0	36.8
2 D, 1 b	75.3	52,870	108,000	49.0	19.5	36.1
4 b	83.1	.....	104,700	.....	20.0	39.2
7 b	90.9	54,300	107,100	50.7	19.5	37.4
Average		59,673	114,475	51.7	17.3	31.3
2 A, 1 c	2.9	65,070	108,900	59.8	21.0	40.5
4 c	10.7	60,100	114,700	52.4	16.5	27.2
7 c	18.5	58,000	115,500	50.2	18.5	35.9
2 B, 1 c	27.7	61,200	115,700	53.0	18.0	34.8
4 c	35.5	61,500	114,300	53.8	20.0	35.6
7 c	43.2	63,300	114,200	55.5	18.0	36.5
2 C, 1 c	51.6	61,760	115,500	53.5	18.5	36.3
4 c	59.3	58,600	112,800	52.0	21.5	36.3
7 c	67.0	63,620	114,700	55.6	18.5	36.9
2 D, 1 c	75.3	63,200	114,700	55.2	17.5	29.6
4 c	83.1	58,460	111,700	52.4	19.5	32.6
7 c	90.9	59,750	109,200	54.7	21.0	41.2
Average		61,213	113,491	54.0	19.0	35.2
General Average		60,045	113,663	52.7	18.3	33.3

TABLE 66—TENSILE TESTS, RAIL-BAR 3—TREATED WITH .1% TITANIUM.

Test Number	Per cent. from top of ingot	Yld. Pnt. lbs. per sq. in.	Tens. Str. lbs. per sq. in.	Ratio per cent.	Elong. per cent. in 2 in.	Reduct. of area per cent.
3 A, 1 a	3.7	63,530	111,400	57.0	6.5	8.3
4 a	11.4	57,380	116,200	49.3	19.5	33.6
7 a	19.2	66,080	119,500	55.3	18.5	32.8
3 B, 1 a	28.3	61,800	116,000	53.3	18.0	32 4
4 a	36.1	61,080	116,100	52.6	19.0	33.7
7 a	43.9	62,520	115,700	54.1	18.5	27.8
3 C, 1 a	52.0	65,080	115,900	56.2	20.0	30.9
4 a	59.9	61,960	114,800	54.0	17.5	31.7
7 a	67.6	65,820	116,000	56.7	18.0	31.1
3 D, 1 a	76.0	63,850	116,000	55.0	20.5	34.8
4 a	83.7	63,820	115,000	55.5	20.0	35.6
7 a	91.5	60,440	113,000	53.5	20.0	35.8
Average		62,780	115,466	54.3	18.0	30.7
3 A, 1 b	3.7	60,570	112,000	54.0	18.5	33.4
4 b	11.4	60,350	120,400	50.1	17.0	24.0
7 b	19.2	67,930	130,600	52.0	13.5	17.2
3 B, 1 b	28.3	62,380	122,600	50.8	15.0	23.4
4 b	36.1	59,480	118,000	50.4	16.5	24.9
7 b	43.9	56,400	110,000	51.2	19.0	33.3
3 C, 1 b	52.0	58,000	110,200	52.6	19.5	33.2
4 b	59.9	59,200	111,800	53.0	18.0	29.4
7 b	67.6	58,880	108,500	54.2	19.0	34.4
3 D, 1 b	76.0	51,090	105,700	48.4	20.0	41.7
4 b	83.7	55,000	103,600	53.1	18.5	39.7
7 b	91.5	56,240	111,500	50.5	19.5	38.1
Average		58,793	113,741	51.6	17.8	31.0
3 A, 1 c	3.7	.....	.....	.....	.....	.....
4 c	11.4	59,220	115,400	51.3	14.5	16.5
7 c	19.2	62,050	117,200	53.0	20.0	35.4
3 B, 1 c	28.3	63,500	116,400	54.5	18.0	33.6
4 c	36.1	65,230	116,400	56.0	19.0	34.5
7 c	43.9	66,220	116,700	56.8	19.0	32.8
3 C, 1 c	52.0	60,980	117,100	52.1	19.5	35.7
4 c	59.9	64,620	116,100	55.6	18.5	27.2
7 c	67.6	62,680	117,000	53.6	19.0	35.0
3 D, 1 c	76.0	65,090	116,800	55.8	18.5	34.1
4 c	83.7	66,060	116,000	56.9	19.0	37.3
7 c	91.5	63,260	114,200	55.4	19.0	30.3
Average		63,537	116,300	54.6	18.5	32.0
General Average		61,651	115,137	53.5	18.1	31.2

TABLE 67—TENSILE TESTS, RAIL-BAR 4—TREATED WITH .2% TITANIUM.

Test Number	Per cent. from top of ingot	Yld. Pnt. lbs. per sq. in.	Tens. Str. lbs. per sq. in.	Ratio per cent.	Elong. per cent. in 2 in.	Reduct. of area per cent.
4 A, 1 a	2.9	63,280	110,800	57.1	16.5	19.7
4 a	10.4	65,160	114,600	56.9	19.5	36.6
7 a	17.8	66,820	116,300	57.4	19.5	37.1
4 B, 1 a	26.9	66,910	117,800	56.8	20.0	33.3
4 a	34.3	66,800	116,400	57.3	19.5	37.6
7 a	41.7	66,700	116,600	57.2	19.5	34.2
4 C, 1 a	50.2	70,440	117,400	59.9	19.0	35.7
4 a	57.6	68,170	112,700	60.5	19.0	37.6
7 a	65.0	69,130	117.400	58.8	20.5	35.3
4 D, 1 a	73.5	67,460	117,600	57.4	20.0	30.3
4 a	80.9	67,280	116,900	57.6	19.0	36.3
7 a	88.3	65,220	113,400	57.5	21.0	39.2
Average		66,947	115,658	57.8	19.4	34.4
4 A, 1 b	2.9	59,600	111,000	53.7	20.5	39.2
4 b	10.4	67,920	121,900	55.7	16.5	32.0
7 b	17.8	73,980	126,400	58.5	16.5	29.8
4 B, 1 b	26.9	74,020	130,100	56.9	15.5	25.7
4 b	34.3	71,060	126,700	56.1	16.5	26.8
7 b	41.7	68,880	125,900	54.7	17 5	30.0
4 C, 1 b	50.2	67,620	118,800	57.0	17.0	27.9
4 b	57.6	65,230	114,200	57.1	19.0	33.7
7 b	65.0	62,980	110,900	56.2	21.0	36.8
4 D, 1 b	73.5	61,860	114,200	54.2	20.5	31.4
4 b	80.9	66,870	112,100	59.6	19.0	20.9
7 b	88.3	68,400	114,700	59.7	18.0	36.9
Average		67,368	18,908	56.6	18.1	31.6
4 A, 1 c	2.9	65,500	116,000	56.5	14.5	24.4
4 c	10.4	61,450	115,700	53.2	19.0	34.0
7 c	17.8	64,770	114,600	56.5	19.0	37.0
4 B, 1 c	26.9	66,780	115,400	56.8	19.5	32.2
4 c	34.3	63,000	114,100	55.2	21.0	41.5
7 c	41.7	64,300	115,500	55.7	20.5	34.8
4 C, 1 c	50.2	64,130	115,000	55.8	19.0	32.4
4 c	57.6	66,770	115,300	57.8	21.0	42.1
7 c	65.0	68,120	115,000	59.2	20.5	32.2
4 D, 1 c	73.5	65,580	117,600	55.8	22.0	35.6
4 c	80.9	54.200	116,800	46.3	20.0	33.0
7 c	88.3	67,060	115,400	58.1	21.5	42.4
Average		64,305	115,533	55.5	19.7	35.1
General Average		66,206	116,700	56.6	19.1	33.7

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The table on page 274 should come under the caption on page 273.
The table on page 275 should come under the caption on page 274.
The table on page 273 should come under the caption on page 275.

TABLE 68—TENSILE TESTS, RAIL-BAR 5—TREATED WITH .4% TITANIUM.

Test Number	Per cent. from top of ingot	Yld. Pnt. lbs. per sq. in.	Tens. Str. lbs. per sq. in.	Ratio per cent.	Elong. per cent. in 2 in.	Reduct. of area per cent.
7 A, 1 a	2.3	.....	.....	.....	.....	.....
4 a	10.0	65,650	115,700	56.8	16.5	23.7
7 a	17.8	62,020	117,300	52.8	21.0	34.6
7B , 1 a	27.6	66,040	117,500	56.2	18.5	36.5
4 a	35.3	65,210	116,000	57.1	18.5	35.2
7 a	43.1	58,520	116,700	50.2	18.0	38.9
7 C, 1 a	50.9	66,500	117,000	56.8	19.0	36.9
4 a	58.7	62,820	119,600	52.5	16.5	33.7
7 a	66.4	64,870	120,000	54.0	18.5	35.7
7 D, 1 a	74.3	61,020	118,300	51.5	18.5	36.8
4 a	82.0	62,460	117,500	53.1	18.5	36.8
7 a	89.8	66,140	117,400	56.3	19.0	38.5
Average		63,750	117,545	54.3	18.4	35.2
7 A, 1 b	2.3	.....	.....	.....	.....	.....
4 b	10.0	62,380	117,000	53.3	16.5	27.3
7 b	17.8	73,340	127,500	57.5	5.0	5.1
7 B, 1 b	27.6	67,760	119,300	56.7	5.5	6.0
4 b	35.3	64,200	121,600	52.8	17.0	30.0
7 b	43.1	67,290	120,200	56.0	17.0	30 0
7 C, 1 b	50.9	63,360	117,700	53.8	17.5	28.3
4 b	58.7	60,400	116,100	52.0	18.5	34.8
7 b	66.4	58,510	114,400	51.2	18.0	34.6
7 D, 1 b	74.3	57,160	112,000	51.1	19.5	37.1
4 b	82.0	59,150	111,800	53.0	20.0	37.6
7 b	89.8	58,160	111,800	52.1	19.5	35.3
Average		62,882	117,218	53.5	15.8	27.8
7 A, 1 c	2.3	.....	.....	.....	.....	.....
4 c	10.0	64,600	116,400	55.5	11.0	13.6
7 c	17.8	66,560	118,400	56.2	18.0	35.2
7 B, 1 c	27.6	67,440	117,300	57.4	18.5	35.1
4 c	35.3	66,720	118,900	56.2	20.0	36.6
7 c	43.1	66,860	118,400	56.4	20.0	36.9
7 C, 1 c	50.9	65,900	118,100	55.7	20.5	37.9
4 c	58.7	68,540	119,400	57.4	18.0	33.4
7 c	66.4	66,050	119,800	55.2	18.5	36.9
7 D, 1 c	74.3	68,720	120,400	57.1	19.0	35.3
4 c	82.0	58,830	119,600	49.2	18.0	37.3
7 c	89.8	68,740	118,700	58.0	21.0	38.2
Average		66,269	118,672	55.8	18.4	34.2
General Average		64,300	117,810	54.5	17.5	32 4

TABLE 69—TENSILE TESTS, RAIL-BAR 6—TREATED WITH .6% TITANIUM.

Test Number	Per cent. from top of ingot	Yld. Pnt. lbs. per sq. in.	Tens. Str. lbs. per sq. in.	Ratio per cent.	Elong. per cent in 2 in.	Reduct. of area per cent.
5 A, 1 a	3.0	5,9600	108,100	55.1	22.5	41.0
4 a	10.7	66,060	113,800	58.0	19.5	37.5
7 a	18.4	61,910	113,400	54.6	18.0	28.0
5 B, 1 a	27.7	67,050	114,700	58.5	17.0	30.0
4 a	35.4	64,800	114,100	58.7	19.0	28.7
7 a	43.1	62,760	113,700	55.2	19.5	34.0
5 C, 1 a	51.3	64,300	113,700	56.6	18.0	29.1
4 a	59.0	64,070	114,900	53.2	20.0	32.2
7 a	66.7	63,930	115,500	55.3	18.5	33.4
5 D, 1 a	75.0	63,100	114,900	55.0	20.5	33.4
4 a	82.7	65,460	114,200	57.3	18.5	28.4
7 a	90.3	64,980	110,800	58.7	17.5	22.6
Average		63,751	113,483	56.3	19.0	31.5
5 A, 1 b	3.0	57,600	109,400	52.7	17.0	28.8
4 b	10.7	62,970	116,000	54.2	19.0	32.9
7 b	18.4	66,900	119,600	56.0	15.5	23.5
5 B, 1 b	27.7	66,580	121,700	54.8	14.0	20.8
4 b	35.4	63,930	120,700	53.0	15.5	32.3
7 b	43.1	61,970	119,800	51.7	15.0	23.3
5 C, 1 b	51.3	64,560	117,000	55.1	15.0	22.6
4 b	59 0	62,560	110,000	56.8	17.5	24.3
7 b	66.7	64,310	116,200	55.3	15.5	26.5
5 D, 1 b	75.0	60,570	110,000	55.1	18.0	28.2
4 b	82 7	58,260	104,800	55.6	21.0	37.3
7 b	90.3	57,900	113,600	56.0	15.0	17.2
Average		62,342	114,900	54.6	16.5	26.4
5 A, 1 c	3.0	60,620	104,400	58.1	21.5	34.3
4 c	10.7	64,520	114,300	56.4	18.0	39.8
7 c	18.4	66,740	113,200	59.0	16.5	29.1
5 B, 1 c	27.7	67,650	114,600	59.1	17.5	29.6
4 c	35.4	63,640	113,000	56.3	18.0	23.7
7 c	43.1	67,980	114,900	59.2	19.5	36.1
5 C, 1 c	51.3	66,170	113,800	58.2	17.5	29.4
4 c	59.0	63,340	114,800	55.2	15.0	29.9
7 c	66.7	68,600	114,700	59.9	20.0	37.9
5 D, 1 c	75.0	66,010	115,300	57.2	20.0	36.4
4 c	82.7	64,610	114,200	56.6	21.0	39.8
7 c	90.3	62,150	112,600	55 3	17.5	23.6
Average		65,169	113,316	57.5	18.5	32.4
General Average		63,754	113,900	56.1	18.0	30.1

TABLE 70—TENSILE TESTS, RAIL-BAR 7—PLAIN STEEL HELD IN LADLE.

Test Number	Per cent. from top of ingot	Yld. Pnt. lbs. per sq. in.	Tens. Str. lbs. per sq. in.	Ratio per cent.	Elong. per cent. in 2 in.	Reduct. of area per centr
6 A, 1 a	2.9	59,040	105,900	55.8	22.5	44.1
4 a	10.5	60,040	108,100	55.5	19.5	38.7
7 a	18.2	63,950	109,900	58.2	19.0	33.8
6 B, 1 a	27.9	62,560	111,100	56.2	20.0	34.8
4 a	35.6	62,380	111,000	56.2	19.5	37.9
7 a	43.3	60,350	109,600	55.1	21.0	36.1
6 C, 1 a	51.7	58,950	111,300	52.9	20.0	32.8
4 a	59.3	62,260	111,900	55.6	20.0	36.4
7 a	67.0	66,930	111,300	60.1	18.5	38.2
6 D, 1 a	75.4	66,100	111,200	59.5	19.5	41.0
4 a	83.0	60,280	107,800	55.9	19.5	33.8
7 a	90.7	55,140	100,400	54.9	22.5	40.8
Average		61,498	109,125	56.3	20.1	37.3
6 A, 1 b	2.9	57,880	102,300	56.5	21.5	42.9
4 b	10.5	62,600	113,000	55.4	17.5	32.7
7 b	18.2	65,620	117,900	55.7	18.0	25.5
6 B, 1 b	27.9	71,570	123,700	57.9	13.5	21.9
4 b	35.6	62,940	119,700	52.6	16.5	27.0
7 b	43.3	65,280	116,000	56.2	17.5	33.7
6 C, 1 b	51.7	59,810	110,400	54.1	19.5	31.1
4 b	59.3	58,670	107,000	54.8	21.0	37.1
7 b	67.0	64,670	108,900	59.4	18.0	36.9
6 D, 1 b	75.4	61,440	110,100	55.7	20.0	32.8
4 b	83.0	58,400	100,100	58.3	21.5	32.3
7 b	90.7	56,660	100,400	56.4	23.0	40.3
Average		62,128	110,791	56.0	18.9	32.8
6 A, 1 c	2.9	60,660	107,600	56.5	22.5	43.5
4 c	10.5	63,570	110,000	57.8	21.0	37.9
7 c	18.2	63,150	108,800	58.1	18.5	34.0
6 B, 1 c	27.9	62,920	108,000	58.2	21.0	35.2
4 c	35.6	64,420	111,600	57.7	20.0	36.4
7 c	43.3	63,880	109,300	58.4	22.0	39.8
6 C, 1 c	51.7	60,460	111,100	54.3	21.0	40.9
4 c	59.3	60,930	110,600	55.0	20.5	32.8
7 c	67.0	65,680	110,300	59.5	21.5	42.8
6 D, 1 c	75.4	65,960	109,600	60.1	21.0	42.3
4 c	83.0	54,650	106,200	51.5	22.5	40.5
7 c	90.7	57,180	102,200	56.0	23.5	43.4
Average		61,955	108,775	56.9	21.2	39.1
General Average		61,860	109,563	56.4	20.1	36.4

The results showing the tensile strengths along the rail-bars are plotted for each bar, in fig. 18, the distance from the top of the ingot figured in per cent. of weight along the bar being represented horizontally and the tensile strength in lbs. per square inch being represented vertically, and the results are shown for the three positions of corner of head, interior of head and flange. It will be noted that in general with all the rail-bars the upper corner of the head and the flange had just about the same tensile strength, while the interior of the head, differed considerably in tensile strength from the metal of the exterior of the section in some portions of the rail-bar, having been higher in part of the top end of the bar and lower in part of the bottom end of the bar. Starting at the top end of the ingot, the tensile strength of the rail-bar at first increased for all three positions in the section. The exterior metal

increased until a distance varying from 10 to 20 per cent. down was reached, after which the strength remained roughly the same except to

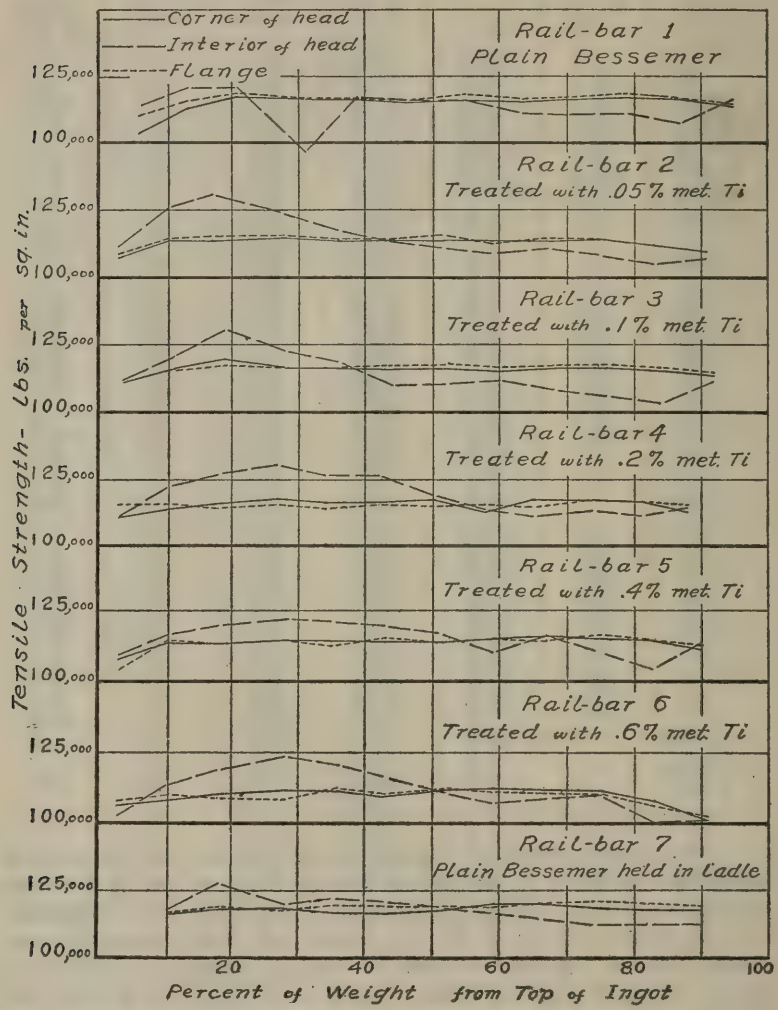

FIG. 18. TENSILE STRENGTH AS RELATED TO DISTANCE FROM TOP OF INGOT.

show a little drop again at the lower end of the bar. The interior metal started at about the same strength, but reached a maximum at distances varying about 17 to 30 per cent. by weight down from the top end of the

ingot. In a general way this point of maximum strength seems to have gone lower down the bar with an increase in the amount of titanium treatment, until the treatment of about .2 per cent. metallic titanium was reached. Continuing downward of the ingot, the strength of the interior

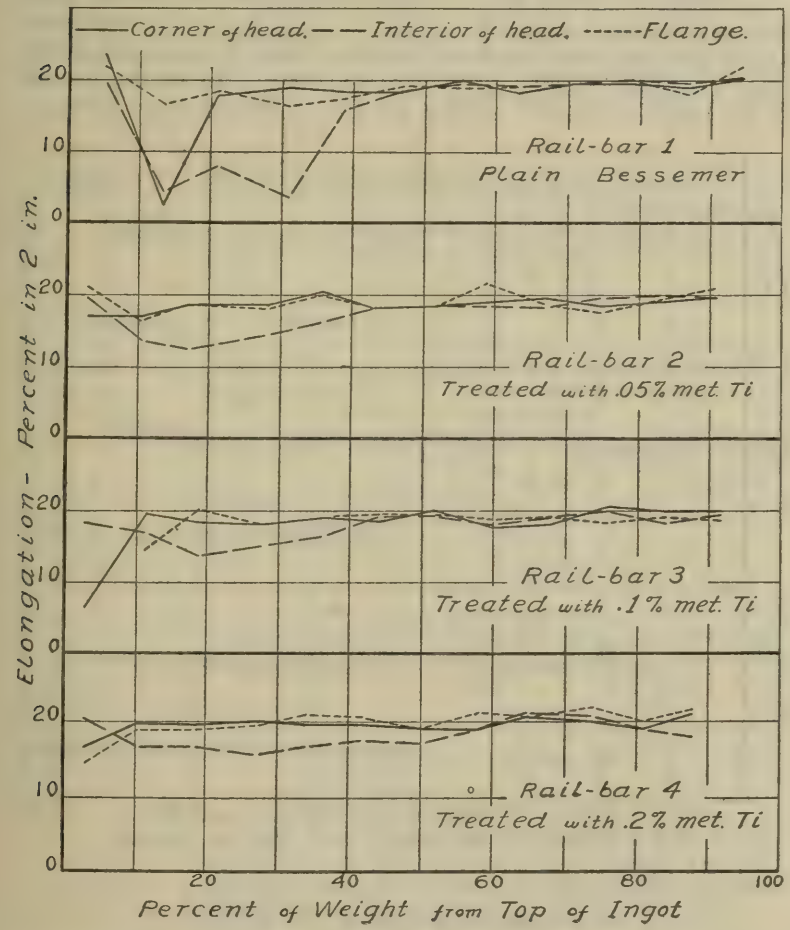

FIG. 19. ELONGATION IN TENSILE TEST OF RAIL-BARS 1, 2, 3 AND 4 AS RELATED TO DISTANCE FROM TOP OF INGOT.

metal of the bar decreased until a minimum was reached at about 85 per cent. down, after which it again increased to about the strength of the exterior metal. The metal was of about uniform strength throughout the section at, roughly, half way down the ingot, but this region of uniform

strength seems also to have gone lower down with increase of titanium treatment up to .2 per cent. treatment, than with the plain steel. One sample from rail-bar 1 of plain steel, number 1B1b, gave a very low tensile strength, due evidently to breaking "short" account of low ductility.

The tensile strength of the exterior portions of the rail-bar averaged roughly about 115,000 lbs. per sq. in. in the part of the bar below 10 to 20 per cent. from the top of the ingot. Close to the top end of the bar, the strength averaged about 5,000 lbs. lower. The tensile strength of the interior metal varied in any one bar within a range of 15,000 or

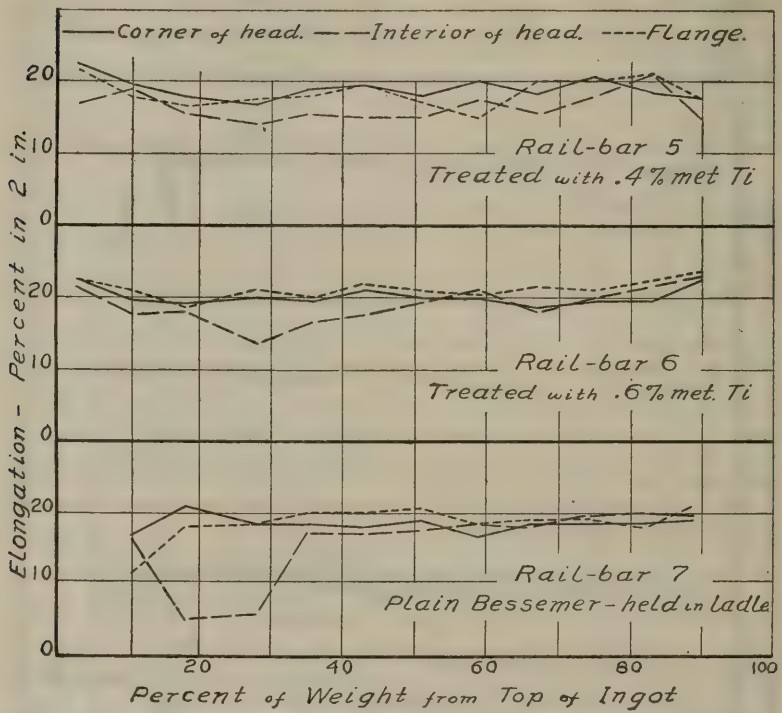

FIG. 20. ELONGATION IN TENSILE TEST OF RAIL-BARS 5, 6 AND 7 AS RELATED TO DISTANCE FROM TOP OF INGOT.

20,000 lbs. per sq. in. The maximum was roughly 122,000 to 131,000 lbs., and the minimum was in general 15,000 or 20,000 lbs. lower. The differences were somewhat greater with the titanium-treated bars than with the plain ones.

The results showing the ductility of each bar are given in figs. 19 and 20, the distance from the top of the ingot figured in per cent. of weight along the bar being represented horizontally and the per cent.

elongation in 2 in. being represented vertically. It will be noted that the flange shows good ductility along the whole bar in all the bars and in general the ductility of the flange is highest at the two ends of the bar. The samples from the corner of the head also showed good ductility along the entire bar except in rail-bar 1, made of plain steel, in which one sample at 13.4 per cent. from the top of the ingot gave only 2.5 per cent. elongation. The interior of the head showed good ductility in the lower two-thirds of the rail-bar in all the bars, but in the upper third

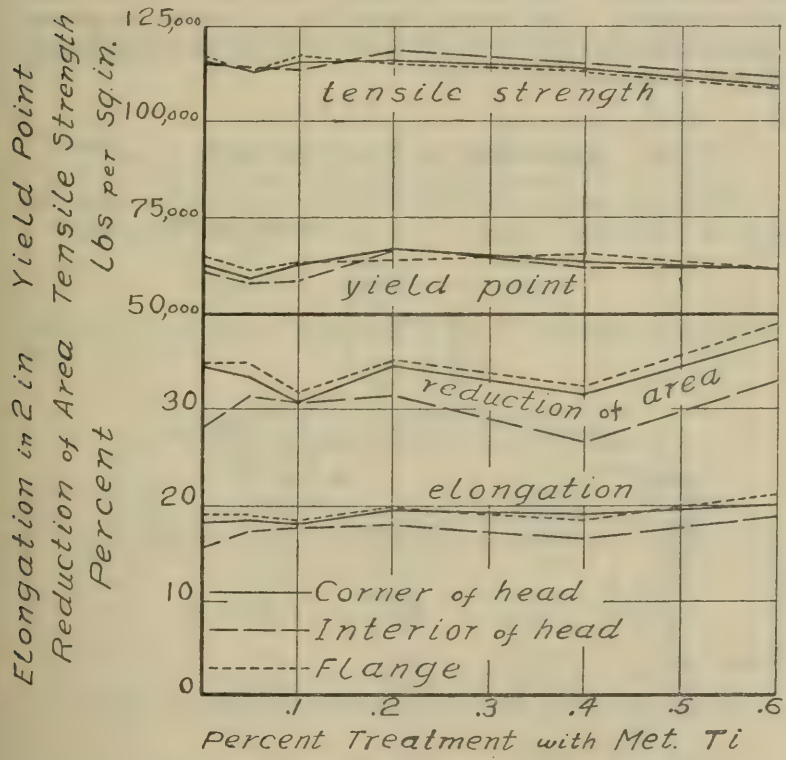

FIG. 21. TENSILE RESULTS AS RELATED TO AMOUNT OF TITANIUM TREATMENT.

of the bar, the two bars made of plain Bessemer steel, numbers 1 and 7, had a zone of low ductility running from about 15 per cent. from the top of the ingot to about 30 per cent. down. The titanium-treated bars showed good ductility in this region, although not as good as higher up or lower down in the bars. The elongation of the exterior metal as represented by the upper corner of the head and by the flange averaged about 18

per cent. in all the bars. The metal from the interior of the head also averaged about 18 per cent. in the lower two-thirds of the bar in all the bars. In the upper third of the bar, the minimum elongation was 4 or 5 per cent. in the plain bars and in the titanium-treated bars ranged from about 12 to 14 per cent.

The average tensile results of each of the three section locations are plotted in relation to the amount of titanium treatment in fig. 21, the per cent. of treatment with metallic titanium being shown horizontally and the tensile strength, yield point, reduction of area and elongation being shown vertically. These curves indicate that as regards the average results of the whole bar, the tensile properties of the rail were influenced but little by the titanium treatment.

CROSS BENDING TESTS OF BASE.

Partial rail sections, one-half inch thick, were cut from each one-third of a rail length from each of the rail-bars, and subjected to a

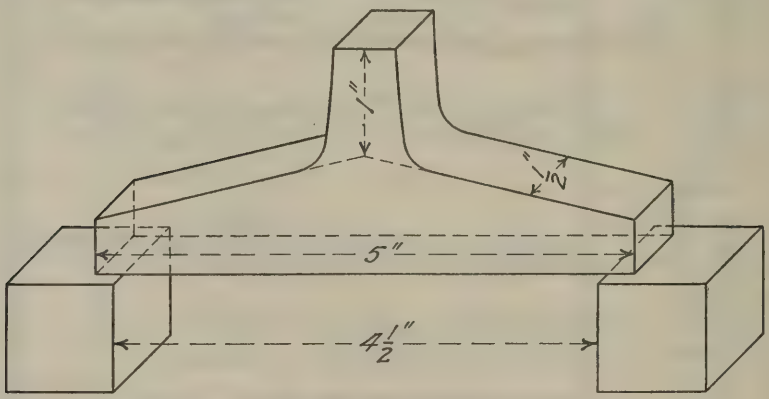

FIG. 22—METHOD OF MAKING TRANSVERSE BENDING TEST OF BASE.

cross bending test of the base, as indicated in fig. 22. The base was supported on blocks near the edges of the flanges, and the web was then given blows with a heavy machinist's hammer until the base was broken. A typical specimen after breaking is shown in fig. 23. In order to have a convenient numerical measure of the bend of the base when broken, the ordinate was measured along the center line from a chord four inches long to the bottom of the base, as indicated in fig. 23. The distance of the break at the bottom of the base to the center line was measured and the depth of the seam, if present, was measured also. The results of these

tests are shown in tables 71 to 76, inclusive, covering rail-bars 1 to 6, inclusive. Rail-bar 7, of plain Bessemer steel, held in the ladle, is not

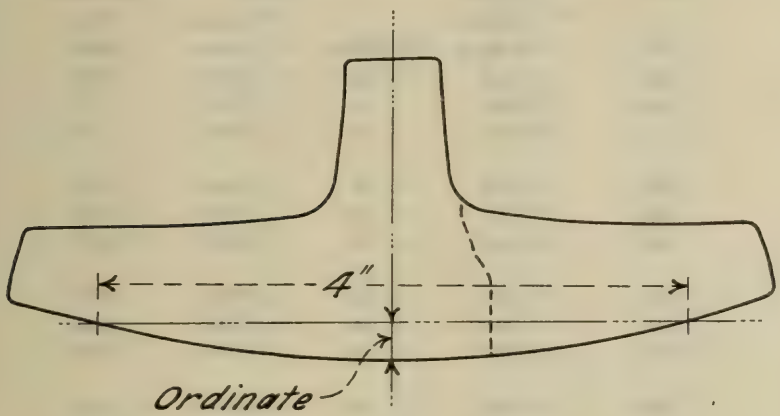

FIG. 23—SAMPLE OF BASE AFTER TEST.

included in the series of tests, because the identification marks on the pieces were lost.

TABLE 71—BASE TESTS, RAIL-BAR 1, PLAIN BESSEMER.

No.	Per cent. from top of ingot.	Ordinate.	External seam.	Distance from center.
1A1	5.7	None	.05	.16
1A4	13.4			
1A7	21.1	.09	None	.47
1B1	30.9	None	None	.72
1B4	38.7	None	None	.79
1B7	46.3	.31	None	1.08
1C1	55.0	.09	None	.22
1C4	62.6	.02	None	.70
1C7	70.4	.09	None	1.41
1D1	79.0	None	.03	.08
1D4	86.8	.17	None	1.04
1D7	94.5	.12	None	1.59

No. 1A7 showed one interior seam.

TABLE 72—BASE TESTS, RAIL-BAR 2, TREATED WITH .05% TITANIUM.

No.	Per cent. from top of ingot.	Ordinate.	External seam.	Distance from center.
2A1	2.9	.24	None	.73
2A4	10.7	.10	None	.71
2A7	18.5	.19	None	.82
2B1	27.7	.08	None	.37
2B4	35.5	.39	None	1.13
2B7	43.2	.16	None	.08
2C1	51.6	.25	None	.16
2C4	59.3	.24	None	.29
2C7	67.0	.21	None	1.76
2D1	75.3	.19	None	.35
2D4	83.1	.17	None	.57
2D7	90.9	.20	None	.36

No. 2A7 had one interior seam. No. 2C4 also had a small interior seam.

TABLE 73—BASE TESTS, RAIL-BAR 3, TREATED WITH .1% TITANIUM.

No.	Per cent. from top of ingot.	Ordinate.	External seam.	Distance from center.
3A1	3.7	.17	None	.30
3A4	11.4	None	.01	.59
3A7	19.2	.06	None	.80
3B1	28.3	.23	None	.64
3B4	36.1	.40	None	.65
3B7	43.9	.06	None	.37
3C1	52.0	.27	None	.26
3C4	59.9	.06	None	.48
3C7	67.6	.03	.02	.21
3D1	76.0	.19	.01	1.46
3D4	83.7	None	.02	.63
3D7	91.5	.11	None	.84

No. 3A1 showed some seams in the interior. Nos. 3A7 and 3B4 each showed one interior seam.

TABLE 74—BASE TESTS, RAIL-BAR 4, TREATED WITH .2% TITANIUM.

No.	Per cent. from top of ingot.	Ordinate.	External seam.	Distance from center.
4A1	2.09	None	.08	.54
4A4	10.4	.21	None	.45
4A7	17.8	.22	None	.84
4B1	26.9	.07	.02	.35
4B4	34.3	.26	None	.72
4B7	41.7	.07	.02	.59
4C1	50.2	.14	.01	.30
4C4	57.6	.41	None	.81
4C7	65.0	.15	None	.69
4D1	73.5	.27	None	.56
4D4	80.9	.04	None	.66
4D7	88.3	.07	.03	.75

No. 4C4 had one interior seam.

TABLE 75—BASE TESTS, RAIL-BAR 5, TREATED WITH .4% TITANIUM.

No.	Per cent. from top of ingot.	Ordinate.	External seam.	Distance from center.
5A1	3.0	.05	.02	1.04
5A4	10.7	.14	None	.51
5A7	18.4	.08	.03	1.30
5B1	27.7	.05	None	.30
5B4	35.4	.02	.03	.22
5B7	43.1	.06	.02	.95
5C1	51.3	.25	None	1.30
5C4	59.0	.03	None	.41
5C7	66.7	.03	None	.04
5D1	75.0	.07	None	.61
5D4	82.7	.09	.02	.63
5D7	90.3	.20	.01	1.14

No. 5A1 had a horizontal seam near web.

TABLE 76—BASE TESTS, RAIL-BAR 6, TREATED WITH .6% TITANIUM.

No.	Per cent. from top of ingot.	Ordinate.	External seam.	Distance from center.
6A1	2.9	.13	.03	.30
6A4	10.5	.27	None	.65
6A7	18.2	.49	None	.86
6B1	27.9	.45	None	1.31
6B4	35.6	.10	.03	.12
6B7	43.3	.34	None	.79
6C1	51.7	.09	.04	.29
6C4	59.3	.27	None	.00
6C7	67.0	.15	None	.12
6D1	75.4	.22	None	.41
6D4	83.0	.07	None	.71
6D7	90.7	.05	None	99

No. 6A1 had large interior seams near and in web.

The results showing the transverse deflections of the bases, or ordinates, are plotted in figure 24 for each of the rail-bars, the distance from the top end in per cent. of the weight of the ingot being shown horizontally and the deflection or ordinate being shown vertically. The pieces which showed longitudinal seams in the bottom of the base are indicated on the diagrams by circles. The two features of most prominence are probably, first, that the deflections vary considerably in most bars from one end of the bar to the other, and second, that there seems to be no relation between the deflection and the distance from the top end of the ingot. Most of the deflections from rail-bar 1 of plain Bessemer steel gave low results. Most of the pieces from rail-bar 2, treated with .05 per cent. titanium, gave good deflections. Rail-bar 3, with .1 per cent. treatment, and rail-bar 4, with .2 per cent. treatment, gave good and bad results, distributed irregularly. Most of the results from rail-bar 5, with .4 per cent. treatment, were low, while those from rail-bar 6, with .6 per cent. treatment, were mostly good. The irregularity of all the results indicates that the deflection in cross bending of the base is not a function of the treatment of the steel or distance from the top of the ingot, but of some factor not taken account of in this investigation.

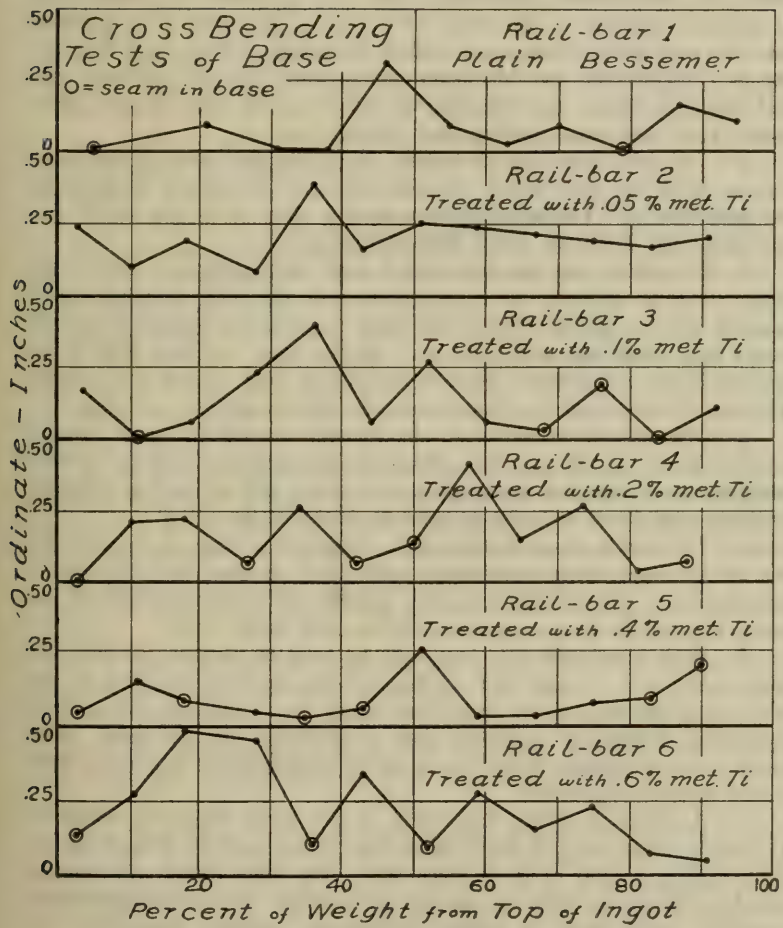

FIG. 24. DEFLECTION IN CROSS BENDING TESTS OF BASE.

SUMMARY.

1. A series of seven Bessemer heats was made treated with varying amounts of ferro-titanium; two of the heats were plain steel and the other five were treated with .05%, .1%, .2%, .4% and .6%, respectively, of metallic titanium in the form of a cold 15 per cent. alloy shoveled into the steel after blowing and adding the spiegel. From each heat two ingots were selected for this experimental work, one for splitting open and chemical survey, and the other to roll in 100-lb. rails for drop tests, tensile tests and cross bending tests of the base.

2. The work was done at Buffalo, N. Y., at the works of the Lackawanna Steel Co., who kindly furnished the steel and all the facilities for the investigation. The ferro-titanium used in these heats was kindly furnished by the Titanium Alloy Manufacturing Co.

3. In making the titanium-treated steel, the metal was held in the ladle for three minutes after the addition of the ferro-titanium before pouring into the molds. One of the heats of plain steel was likewise held in the ladle while the other was not. All the heats had been held in the converter for 2½ minutes after blowing and after adding the spiegel. The ingots were made in plain iron molds without any top covering.

4. One ingot from each heat, after being soaked in the usual manner, was set aside to cool and was afterward split open to note its internal condition as to size and distribution of cavities, and to use for obtaining drillings with which to make a chemical survey of the ingot.

5. The ingots of plain steel each contained a large cavity near the top of the ingot whose appearance indicated it to have been due mostly or entirely to the collection of gas and, in addition, the metal of the upper fifth of the ingot was honeycombed with small holes.

6. With treatments of .1 per cent. or over of metallic titanium, the ingots each had a large main cavity, but the metal surrounding it was solid, or practically so, but in addition there was a tapering extension of the cavity downward, apparently due to shrinkage of the metal. With .05 per cent. treatment, there was a partial solidifying of the above mentioned surrounding metal.

7. A chemical survey was made of the seven ingots by means of 15 samples from each of five vertical rows from one-half of each section face, making a total of 75 samples from each ingot, minus the samples which could not be taken on account of cavities. On each sample determinations were made of carbon, phosphorus, sulphur, manganese and silicon, and on the samples of one ingot, of titanium also.

8. With titanium treatments of .1 per cent. or over of metallic titanium, the segregation of carbon, phosphorus and sulphur was much less than in the plain Bessemer steel, but with .05 per cent. treatment the segregation was not less than in the plain steel.

9. The negative segregation which occurs in the interior and lower part of the ingot seems to have been not greatly influenced by the titanium

treatment, but with treatments of .1 per cent or over of metallic titanium there was not a concentrated collection of the segregating elements, carbon, phosphorus and sulphur, in the interior and upper part of the ingot.

10. With treatments of .05 per cent. and .1 per cent of metallic titanium, the steel contained only traces of titanium, and with treatments of .2, .4 and .6 per cent., the steel contained a little over .02 per cent. titanium.

11. The entire rail-bar of each of the ingots used for rails was used for drop tests, tensile tests and cross bending tests of the base, and was divided into units of one-third rail length, or 11 ft. each. From each 11 ft., 1 ft. was cut for tensile test and base test, then 5 ft. for drop test with the head in tension, and the other 5 ft. was used for drop test with the base in tension.

12. The treatment with titanium improved the ductility, as measured in the drop test, of rail made from the upper fourth of the ingot, and more when tested with the head in tension than with the base in tension. The treatment had little, if any, influence on the ductility in the drop test of rail made from the lower three-fourths of the ingot. The influence of titanium in this respect seemed not to be dependent on the amount used within the range of the amounts used in this work, of .05 per cent. to .6 per cent. metallic titanium and introduced by throwing the alloy into the pouring ladle.

13. Rails made of Bessemer steel treated with .1 per cent. or more of metallic titanium, contained large internal flaws at distances varying from about 10 to 18 per cent. by weight from the top of the ingot. With plain Bessemer steel or with .05 per cent. treatment, internal flaws were absent or were close to the top. The ingots had been made by pouring the steel into plain iron molds and no top covering was used on the steel after pouring.

14. The titanium treatment seemed to have no influence on the deflection of the rails in the drop test.

15. Tensile tests were made from each third of a rail length along each of the rail-bars, one sample from the upper corner of the head, one from the interior of the head near the web, and the other from the flange.

16. The tensile strength was influenced but little by the titanium treatment. The exterior portions of the rail-bar averaged, roughly, about 115,000 lbs. per sq. in. in the part of the bar below 10 to 20 per cent. from the top of the ingot. Close to the top end of the bar, the strength averaged about 5,000 lbs. lower. The tensile strength of the interior metal varied in any one bar within a range of 15,000 or 20,000 lbs. per sq. in. The maximum was, roughly, 122,000 to 131,000 lbs. and the minimum was in general 15,000 or 20,000 lbs. lower. The differences were somewhat greater with the titanium-treated bars than with the plain ones.

17. The tensile strength of the interior metal varied in a general way with the distribution of carbon; that is, it was a maximum at about

one-fourth way down the ingot and a minimum at about 85 per cent. down from the top.

18. The exterior metal showed good ductility in the tensile test in all the rail-bars. The interior of the head also showed good ductility in the lower two-thirds of the rail-bar in all the bars, but in the upper third of the bar, the two bars made of plain Bessemer steel had a zone of low ductility running from about 15 per cent. by weight from the top of the ingot to about 30 per cent. down. The titanium-treated bars showed good ductility in this region, although not as good as higher up or lower down in the bars.

19. Cross-bending tests were made of the base of one-half inch sections cut from each one-third of a rail length along each bar. The base was supported on blocks near the edges of the flanges and the section given blows with a heavy machinist's hammer until the base was broken, and the amount of bending of the base was measured.

20. The cross bends of the base varied considerably in most bars from one end of the bar to the other, but there was no relation between the amount of cross bend and the distance from the top end of the ingot. The titanium treatment also seemed not to influence the result in the cross-bending test of the base.

21. To sum up, the use of amounts of .1 per cent. or more of metallic titanium in the manner described, prevents the "honey-combed" condition of the upper part of ingot found in plain Bessemer steel, but is also attended with a larger and deeper "pipe." The heavy segregation or concentration of carbon, phosphorus and sulphur found in the interior and upper part of ingots of plain Bessemer steel is largely avoided, but the mild negative segregation found in the interior and lower part of the ingot is not materially altered. The brittle zone found in rail of plain Bessemer steel from the upper part of the ingot, as determined by drop and tensile tests, was avoided, but the properties of the rail from the lower two-thirds of the ingot were not changed. Large internal flaws were found in rail considerably lower down from the top of the ingot with steel treated as mentioned than in rail made from plain steel. Treatments with .05 per cent. metallic titanium produced the above results only in part, but treatments above .1 per cent. had only little additional influence.

Appendix D.

PIPELESS INGOTS.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report covers an investigation of two special ingots made by the Standard Steel Works Co., at Burnham, Pa., by a process which prevents the formation of a "pipe" in the interior of the ingot. They were made at the request of Mr. Daniel Willard, President of the American Railway Association, and shipped to the Maryland Steel Co., at Sparrows Point, Md., at which point the author took hold of the matter of testing them. One ingot was split open to note its internal condition as regards cavities and to take samples for a chemical survey, and the other ingot was rolled into 85-lb. rails, which were used for drop tests and transverse tests of the base. These tests were all made at Sparrows Point at the works of the Maryland Steel Co., who kindly furnished all the necessary facilities.

MANUFACTURE.

The steel used was acid open-hearth steel, treated with about .25 per cent. of a 15 per cent. ferro-titanium alloy. The recarburizer was added partly as 80 per cent. ferro-manganese, which was added in the furnace, and partly as 50 per cent. ferro-silicon and 15 per cent. ferro-titanium, which were added together in the ladle after twelve to eighteen inches of metal had entered it. The ingots were octagonal, 20 inches diameter, and made in molds 6 ft. high inside, with a sand head 24 inches deep, superimposed on top of mold. The ingots were top poured and immediately after pouring the metal was thoroughly covered with a high grade of powdered graphite. They were then allowed to stand until cool. The method of applying the sand core is shown in figure 1. When cool these ingots each had a deep cup on top, which cupped part was cut off at Burnham before shipment of the ingots to Sparrows Point. They then measured 78½ inches long, 19⅞ inches in diameter at the bottom, 20½ inches in diameter at the top, one weighed 7,200 lbs. and the other 7,250 lbs. The amount cut off before shipment equaled about 3.3 per cent.

INGOT.

Figure 2 shows one of the ingots cut open, the surface shown being a longitudinal plane about 1 inch from the axis of the ingot, and it will be noted that the metal is solid throughout the ingot, except for a slight spongy condition at the top and a few defects at the axis of the ingot about one-third way down. It was unfortunate that the top of this ingot was cut off previous to the splitting, but figure 3 is given showing the top of another ingot cast by the same process, showing how the top cups down.

The method of laying out the ingot for taking samples for a chemical survey is shown in the drilling diagram, figure 4, and the ingot as drilled is shown in figure 5, the surface shown being close to the axial

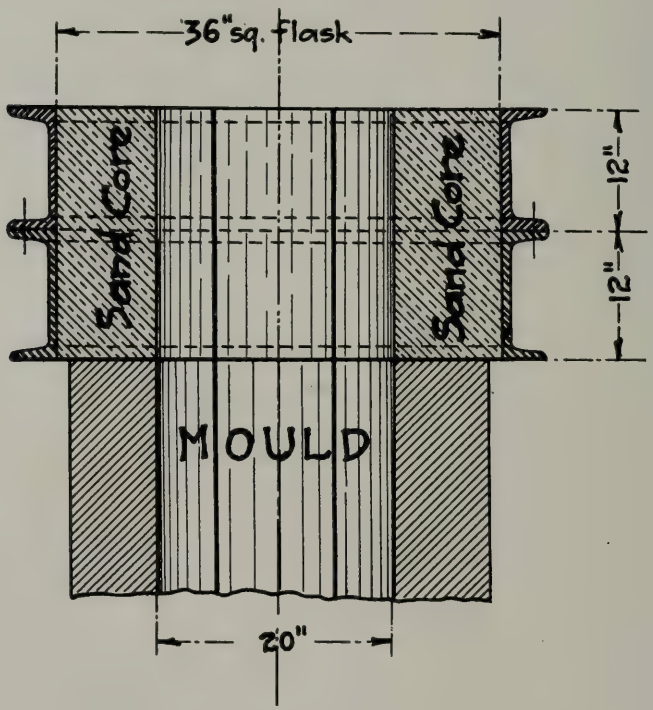

FIG. 1—METHOD OF APPLYING SAND CORE ON TOP OF MOLD.

plane. Determinations were made on all samples of carbon (by combustion), phosphorus and sulphur, and on a few samples determinations were also made of manganese, silicon, copper and titanium. The carbon, phosphorus and sulphur results are shown in table 1. The average com-

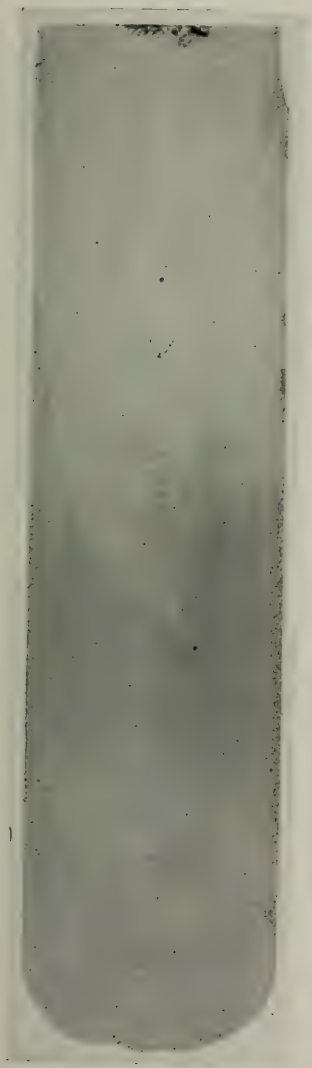

FIG. 2—INGOT SPLIT, LONGITUDINAL PLANE ABOUT 1 INCH FROM AXIS.

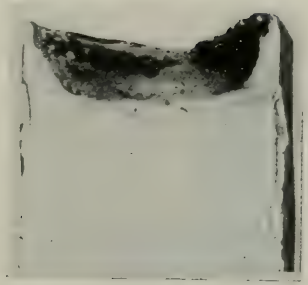

FIG. 3—SHOWING CUPPED TOP OF ANOTHER INGOT.

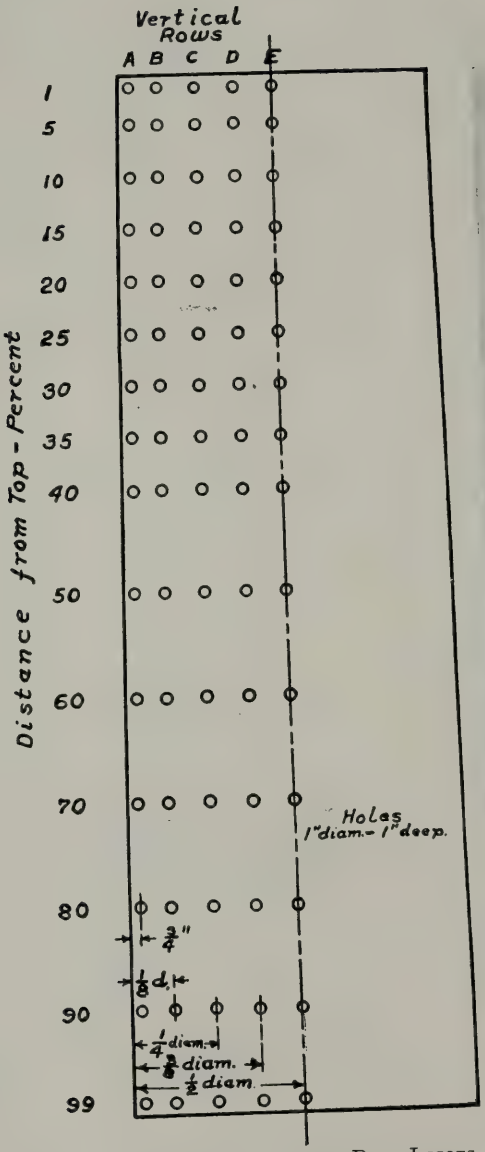

FIG. 4—DRILLING DIAGRAM FOR RAIL INGOTS.

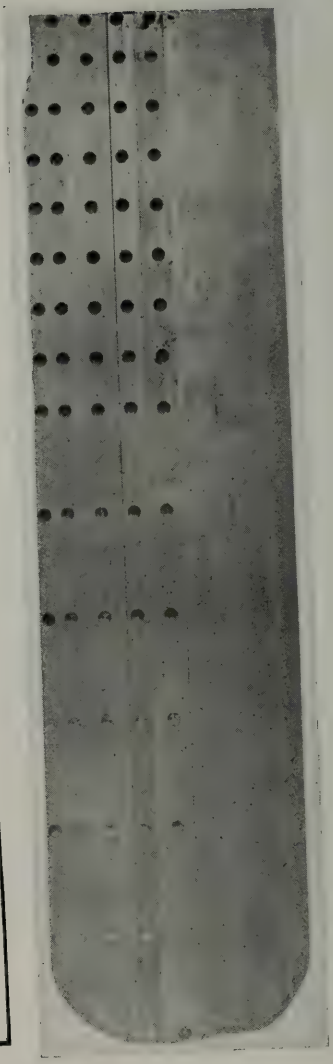

FIG. 5—INGOT DRILLED FOR ANALYSIS. LONGITUDINAL AXIAL PLANE.

	%	A	B	C	D	E
CARBON.	1		.576	.642	.906	1.022
	5		.554	.570	.764	.791
	10	.566	.572	.565	.586	.607
	15	.594	.580	.582	.592	.588
	20	.646	.646	.648	.620	.600
	25	.612	.590	.638	.628	.642
	30	.628	.620	.600	.620	.596
	35	.604	.626	.600	.636	.798
	40	.570	.562	.564	.575	.568
	50	.576	.572	.580	.582	.652
	60	.602	.604	.596	.573	.569
	70	.584	.582	.586	.570	.570
	80	.578	.560	.572	.574	.560
	90	.576	.570	.554	.552	.558
	99				.595	.582
PHOSPHORUS	1		.028	.042	.050	.053
	5		.032	.031	.040	.043
	10	.034	.033	.036	.038	.039
	15	.038	.037	.039	.036	.039
	20	.037	.036	.038	.038	.039
	25	.037	.038	.037	.035	.032
	30	.038	.037	.037	.037	.039
	35	.038	.039	.036	.037	.048
	40	.037	.039	.036	.038	.035
	50	.036	.037	.036	.038	.045
	60	.036	.037	.034	.035	.032
	70	.035	.035	.037	.035	.036
	80	.035	.035	.038	.036	.035
	90	.037	.038	.035	.034	.034
	99				.037	.037
SULPHUR.	1		.038	.059	.069	.079
	5		.040	.040	.057	.059
	10	.050	.047	.047	.045	.052
	15	.050	.040	.049	.050	.048
	20	.051	.051	.048	.044	.049
	25	.049	.051	.043	.049	.046
	30	.050	.050	.051	.048	.047
	35	.049	.046	.050	.049	.068
	40	.051	.050	.045	.044	.048
	50	.042	.045	.040	.037	.046
	60	.035	.041	.044	.040	.039
	70	.041	.045	.042	.032	.044
	80	.047	.047	.043	.041	.042
	90	.043	.050	.040	.040	.038
	99				.043	.037

TABLE I—CARBON, PHOSPHORUS AND SULPHUR IN THE INGOT.

position of the steel in the ingot, as determined by taking the averages of samples 60A, 70A, 80A, 90A, 99E, and also 99D, on those elements of which determinations were made, was as shown in table 2.

TABLE 2—AVERAGE COMPOSITION.

Carbon	.586
Phosphorus	.036
Sulphur	.041
Manganese	.64
Silicon	.25
Copper	.15
Titanium	nil

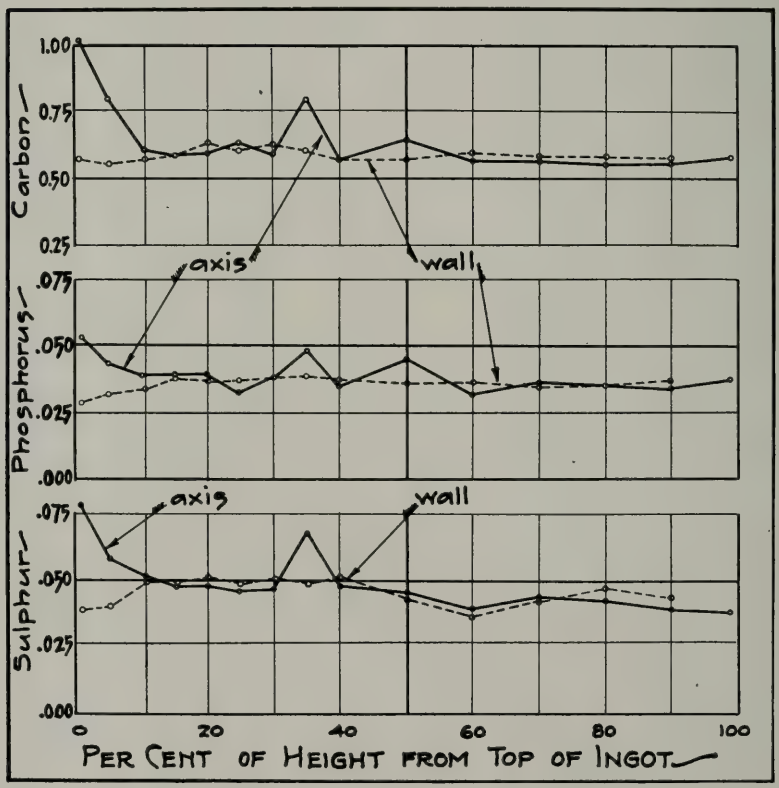

FIG. 6—CARBON, PHOSPHORUS AND SULPHUR PLOTTED IN RELATION TO DISTANCE FROM TOP OF INGOT.

At any given distance from the top of the ingot, the extreme variations in composition are generally shown at the axis and the walls of the ingot, and to show conveniently the changes from the top to the

bottom of the ingot, figure 6 is given, showing the plotted results for carbon, phosphorus and sulphur at the axis and in the wall of the ingot, the amount of the element being shown vertically and the per cent. from the top of the ingot horizontally. It will be noted that the axis shows considerable segregation of carbon, phosphorus and sulphur at the top of the ingot for a distance of between 5 and 10 per cent. down. At a distance of 35 per cent. down, the axis also shows considerable elevation in these elements, and at the place which is shown on the photograph as a defect in the ingot. Four additional samples were taken around hole 35E, with a one-half inch drill, centered ⅜ inch from the outside of hole 35E; No. 1, above; No. 2, to the right; No. 3, below, and No. 4 to the left. The results of the analyses of these samples are shown in table 3.

TABLE 3—SAMPLES AROUND HOLE 35E.

	No. 1.	No. 2.	No. 3.	No. 4.
Carbon	.480	.544	.640	.631
Phosphorus	.021	.025	.036	.031
Sulphur	.033	.036	.051	.049
Manganese	.62	.68	.67	.69
Silicon	.225	.220	.226	.221

It will be seen from these results that the high content of metalloids was almost confined to the sample taken as laid out, and that some of the material immediately around it even showed negative segregation.

TESTS MADE OF RAILS.

The second ingot was the same size as the first, and made from steel of about the same composition from another heat. It was rolled into 85-lb. rail of the A. S. C. E. section, and the entire rail-bar was used for drop tests and transverse tests of the base. Each rail was divided into units of one-third rail length, or 11 ft. each, and from each 11 ft., one foot was cut, then 5 ft. for drop test with the head in tension, and the other 5-ft. piece was used for drop test with the base in tension. The 1-ft. piece was not used, but merely set aside. From the fore end of each 5-ft. piece a section one inch long was cut off for transverse bending test of the base. The distance of each piece from the top of the original ingot, figured in lbs. and in per cent., to the middle of the piece tested, is shown in table 4.

TABLE 4—DISTANCES FROM TOP OF ORIGINAL INGOT.

Test.	Lbs.	Per Cent.	Test.	Lbs.	Per Cent.
A2	634	8.8	B2	1,635	22.8
3	776	10 8	3	1,777	24.8
5	946	13.2	5	1,947	27.2
6	1,088	15.2	6	2,089	29.1
8	1,258	17.5	8	2,259	31.6
9	1,400	19.5	9	2,401	33.5
C2	2,607	36.3	D2	3,566	49.7
3	2,749	38.3	3	3,708	51.7
5	2,919	40.7	5	3,878	54.1
6	3,061	42.7	6	4,020	55.8
8	3,231	45.1	8	4,190	58.4
9	3,373	47.0	9	4,332	60.4
E2	4,549	63.4	F2	5,501	76.7
3	4,691	65.4	3	5,643	78.7
5	4,861	67.8	5	5,813	81.0
6	5,003	69.8	6	5,955	83.0
8	5,173	72.1	8	6,125	85.4
9	5,315	74.1	9	6,267	87.4
G2	6,454	90.0	G5	6,766	94.4
3	6,596	92.0	6	6,908	96.4

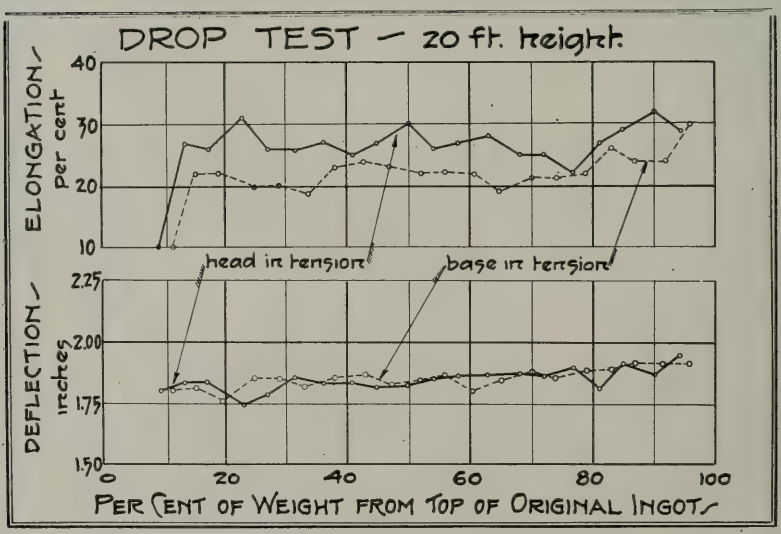

FIG. 7—ELONGATION AND DEFLECTION IN DROP TEST, PLOTTED IN RELATION TO DISTANCE FROM TOP OF INGOT.

DROP TESTS with HEAD in TENSION - 20 ft.				
TEST NUMBER	PER CENT FROM TOP OF INGOT	NUMBER OF BLOWS	DEFLECTION after 1ST BLOW	ELONGATION PER CENT.
A-2	8.8	2	1.80	10
A-5	13.2	3	1.83	27
A-8	17.5	4	1.83	26
B-2	22.8	3	1.74	31
B-5	27.2	3	1.78	26
B-8	31.6	4	1.85	26
C-2	36.3	3	1.83	27
C-5	40.7	4	1.83	25
C-8	45.1	4	1.82	27
D-2	49.7	3	1.82	30
D-5	54.1	4	1.85	26
D-8	58.4	3	1.86	27
E-2	63.4	3	1.86	28
E-5	67.8	3	1.87	25
E-8	72.1	4	1.86	25
F-2	76.7	4	1.90	22
F-5	81.0	3	1.81	27
F-8	85.4	3	1.91	29
G-2	90.0	3	1.87	32
G-5	94.4	3	1.95	29
DROP TESTS with BASE in TENSION - 20 ft.				
A-3	10.8	2	1.80	10
A-6	15.2	3	1.80	22
A-9	19.5	4	1.76	22
B-3	24.8	3	1.85	20
B-6	29.1	3	1.85	20
B-9	33.5	3	1.82	19
C-3	38.3	3	1.85	23
C-6	42.7	3	1.86	24
C-9	47.0	3	1.82	23
D-3	51.7	3	1.84	22
D-6	55.8	3	1.86	22
D-9	60.4	3	1.80	22
E-3	65.4	3	1.84	19
E-6	69.8	3	1.87	21
E-9	74.1	3	1.85	21
F-3	78.7	3	1.88	22
F-6	83.0	3	1.89	26
F-9	87.4	3	1.87	24
G-3	92.0	3	1.91	24
G-6	96.4	3	1.91	30

TABLE 5—RESULTS OF DROP TESTS.

DROP TESTS.

Six drop tests were made of each rail, three with the head in tension and three with the base in tension. The tup was 2,000 lbs., the height of drop was 20 ft., the supports were three ft. apart and the anvil was the standard spring-supported anvil of 20,000 lbs. The deflection or permanent set was measured after the first blow, and was taken as the distance between a three-ft. straight edge and the part of the rail where struck by the tup. Gage marks one inch apart were put on the side in tension for a distance of six inches, and the length of the space which stretched most at failure was determined and taken as the measure of ductility of the rail. The results of the drop tests are shown in table 5, showing the test number, the distance in per cent. from the top of the original ingot, the set after the first blow, the number of blows that it took to break the rail and the per cent. of stretch at failure. For more convenient comparison, the elongation and deflection results are plotted in figure 7, as related to the distance from the top of the ingot.

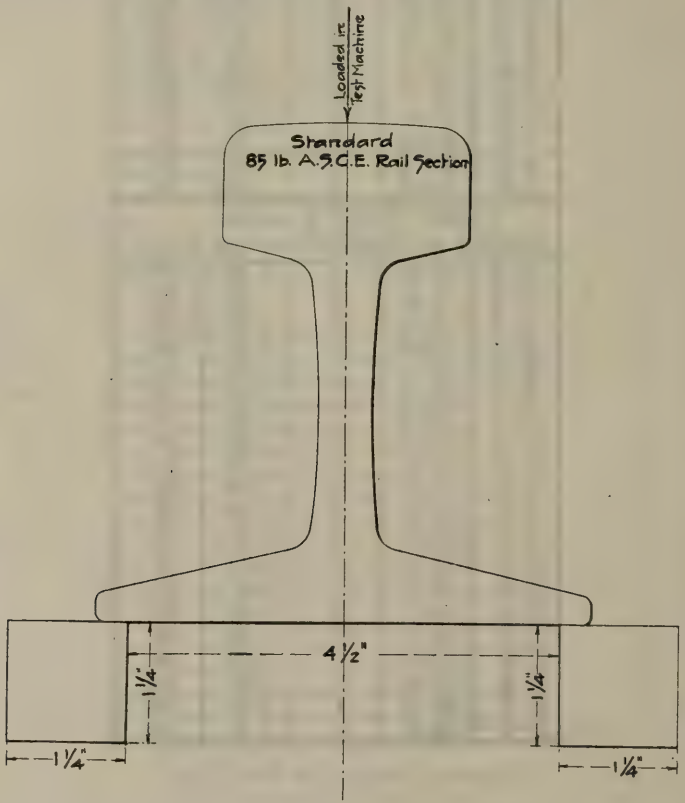

FIG. 8—METHOD OF MAKING TRANSVERSE BENDING TEST OF BASE. SECTIONS OF RAIL WERE 1 INCH THICK.

Test No	Percent From Top	Width.	Load	Deflection	Distance From Center	Seam.	Elongation in 1
A 2	7.8	1.02	18,750	.19	1.95	.05	.04
A 3	9.8	1.02	20,940	.37	1.04	None	.10
A 5	12.2	1.04	15,560	.05	.66	.03	.02
A 6	14.2	1.08	22,390	.38	.74	None	.13
A 8	16.5	1.04	21,920	.44	1.24	None	.12
A 9	18.5	1.07	22,610	.41	1.06	None	.11
B 2	21.8	1.07	22,200	.31	.68	None	.09
B 3	23.8	1.03	20,740	.26	.74	None	.08
B 5	26.2	1.06	21,300	.34	.70	None	.11
B 6	28.1	1.05	21,050	.21	.86	None	.08
B 8	30.6	1.00	20,150	.34	1.10	None	.09
B 9	32.5	1.06	21,220	.30	1.18	None	.09
C 2	35.3						
C 3	37.3	1.03	19,600	.30	1.45	None	.05
C 5	39.7	1.02	21,170	.43	1.18	None	.12
C 6	41.7	1.02	21,150	.48	1.02	None	.13
C 8	44.1	1.06	20,850	.28	.72	None	.08
C 9	46.0	1.06	20,960	.37	1.22	None	.10
D 2	48.7	1.01	20,000	.36	.82	None	
D 3	50.7	1.02	20,800	.34	.86	None	
D 5	53.1	1.02	19,820	.32	1.28	None	.09
D 6	54.8	.97	19,100	.32	1.10	None	.10
D 8	57.4	1.00	18,400	.23	1.40	None	.06
D 9	59.4	1.03	20,320	.34	1.27	None	.08
E 2	62.4	1.02	18,640	.20	1.64	Small	.04
E 3	64.3	1.03	19,400	.23	1.08	None	.07
E 5	66.8	1.05	21,000	.32	1.26	None	.10
E 6	68.8	.96	19,000	.43	1.28	None	.12
E 8	71.1	1.04	17,700	.22	1.30	None	.
E 9	73.1	.95	18,900	.32	.76	None	.12
F 2	75.7	1.03	20,600	.32	.72	None	
F 3	77.7	1.02	20,000	.28	1.20	None	
F 5	80.0	1.11	22,700	.34	.98	None	
F 6	82.0	1.02	18,700	.20	.20	.02	
F 8	84.4	1.02	19,500	.26	1.40	None	
F 9	86.4	1.04	20,200	.28	.94	None	
G 2	89.0	.99	19,300	.27	1.02	None	.07
G 3	91.0	1.03	21,000	.43	.84	None	.11
G 5	93.4	1.03	20,500	.37	1.12	None	.08
G 6	95.4	1.05	20,500	.30	92	None	.10
G 8	97.4	.90	16,500	.25	1.54	.14	

Table 6—Results of Transverse Bending Tests of Base.

An attempt was made to crop off as little as possible from the top end of the bloom, but in order to leave it in suitable condition for rolling, about 7½ per cent. of the original ingot had to be sheared off the top end of the bloom. It will be noted from the diagrams that the rail-bar at 13 per cent., or lower down, shows very good ductility, averaging about 21 per cent. with the base in tension, and about 26 per cent. with the head in tension. Closer to the top the ductility was not so good, although the rail was not brittle.

The diagrams indicate that the rail-bar was stiffest at about 20 per cent. from the top and tended to become less stiff downward of the ingot.

TRANSVERSE BENDING TEST OF BASE.

Transverse bending tests of the base were made of sections one inch long, taken from the fore end of each of the pieces used for drop

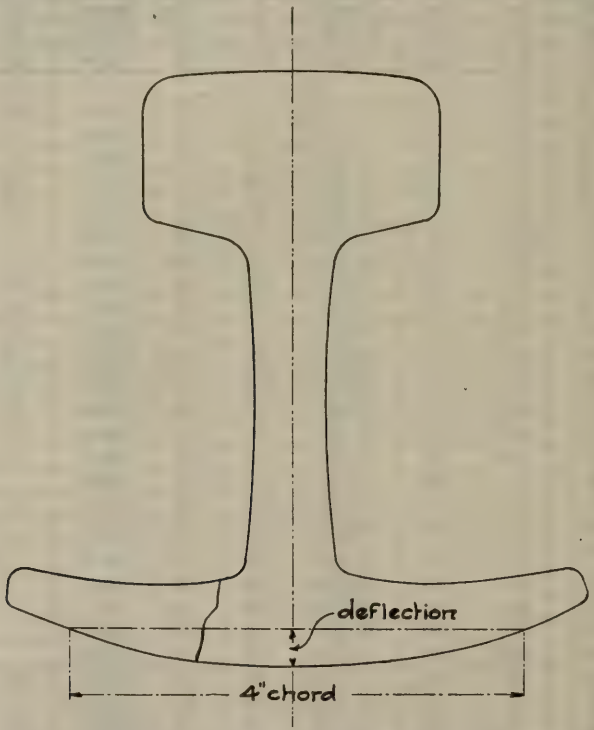

FIG. 9—SAMPLE OF RAIL SECTION AFTER MAKING TRANSVERSE BENDING TEST OF THE BASE.

test by supporting the section on blocks near the edges of the flanges, as shown in figure 8. This was done in the test machine, and the load measured which was required to break the section. The amount that

the base bent before breaking was determined by measuring the distance along the center line from the bottom of the base to a four-inch chord. The distance from the center line to the point where the fracture occurred at the bottom of the base was also measured. The amount that the base stretched cross-wise was determined by putting gage marks one inch apart across the base, and the length of the space containing the break was measured after failure and taken as the measure of transverse ductility. The results of these tests are shown in table 6 and a sample of one of the pieces after breaking is shown in figure 9.

The results showing the load and transverse elongation in relation to the distance from the top end of the ingot are plotted in figure 10. It will be noted that all of the samples showed some stretch before the base broke off, and most of them over 5 per cent. It is also interesting to note from the table that only one sample broke close to the center of the base, and this was one of the few samples that showed an external seam.

SUMMARY.

1. This report deals with an investigation of two special ingots made by the Standard Steel Works Co., at Burnham, Pa., by a process which prevents the formation of a "pipe" in the interior of the ingot.

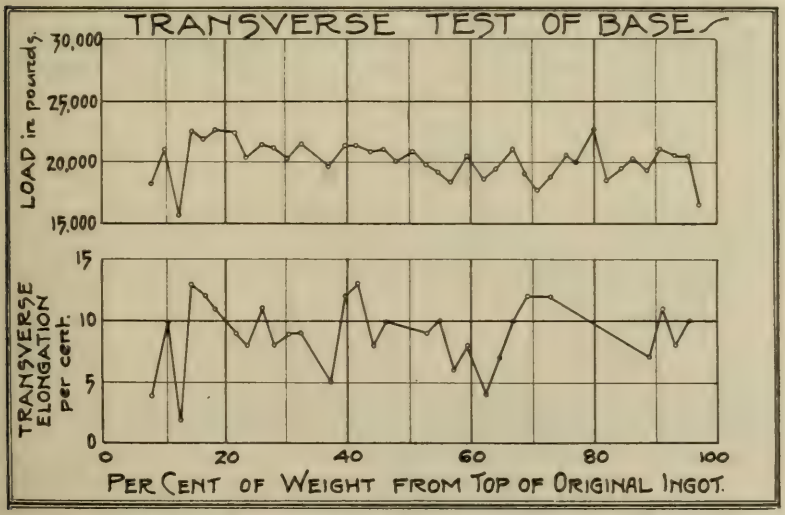

FIG. 10—LOAD AND ELONGATION IN TRANSVERSE BENDING TEST OF THE BASE PLOTTED IN RELATION TO DISTANCE FROM THE TOP OF THE INGOT.

The steel was acid open-hearth steel, of about .6 per cent. carbon, treated with titanium. The ingots were shipped to the Maryland Steel Co., at Sparrows Point, Md., where they were tested.

2. One ingot was split open and a chemical survey made of it. The other was rolled into 85-lb. A. S. C. E. rails, and used for drop tests and transverse tests of the base.

3. The metal was solid throughout the ingot except for a slight spongy condition at the top, and a few defects at the axis, about one-third way down. The top was cupped down, but there was no "pipe" in the interior; in other words, the "pipe" was on the outside.

4. At the top of the ingot there was considerable segregation of carbon, phosphorus and sulphur around the axis, extending downward for a distance of 5 to 10 per cent. of the height of the ingot. Otherwise, the ingot was, in general, of fairly uniform composition.

5. The rail-bar showed good ductility in the drop test, averaging about 21 per cent. with the base in tension, and about 26 per cent. with the head in tension, except the upper end, amounting to 13 per cent. of the weight of the ingot, where the ductility was lower.

6. The rail-bar was stiffest at about 20 per cent. of the weight of the ingot from the top and tended to become less stiff downward of the ingot.

7. All the samples tested in the cross-bending tests of the base showed some stretch before the base broke off, and most of them over 5 per cent.

Appendix E.

TRANSVERSE DUCTILITY OF BASE OF RAILS.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report is given to present a description of a method intended primarily to test the transverse ductility of the bottom of the base of a rail and which also measures the load required to break the base of the rail supported near the edges of the flanges. The results of a few tests are also recorded. This work was done at Buffalo, N. Y., at the works of the Lackawanna Steel Co., who kindly furnished all the material and facilities for doing the work. Suggestions concerning the method of test came from a number of sources, and the author wishes in particular to acknowledge his indebtedness to the suggestions made by Mr. John Brunner of the Illinois Steel Co. and Mr. F. E. Abbott of the Lackawanna Steel Co.

METHOD OF TEST.

The method of making the test was to support a piece of rail about 2 ft. long on two supports placed opposite each other near the edges of the

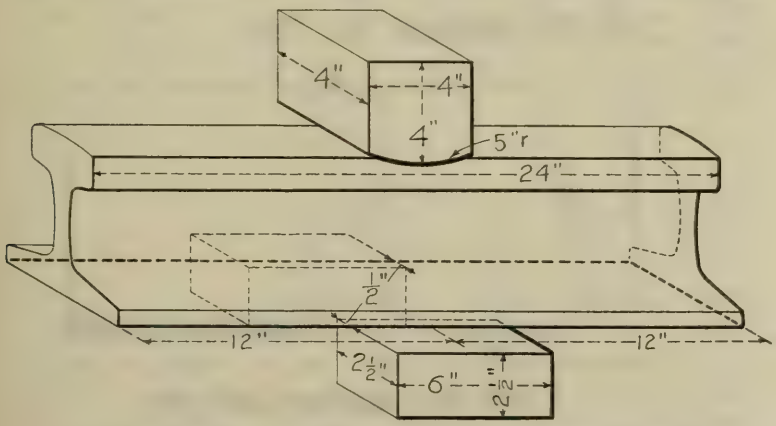

Fig. 1—Method of Making Transverse Test of Base.

flanges under the middle of the length of the rail. The supports were 6 in. long and placed one-half inch in from the sides of the flanges. The load was applied in the test machine through a block with a surface of

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contact on the rail of 5-in. radius. Fig. 1 shows the general arrangement, and the details of the blocks and die are shown in Fig. 2.

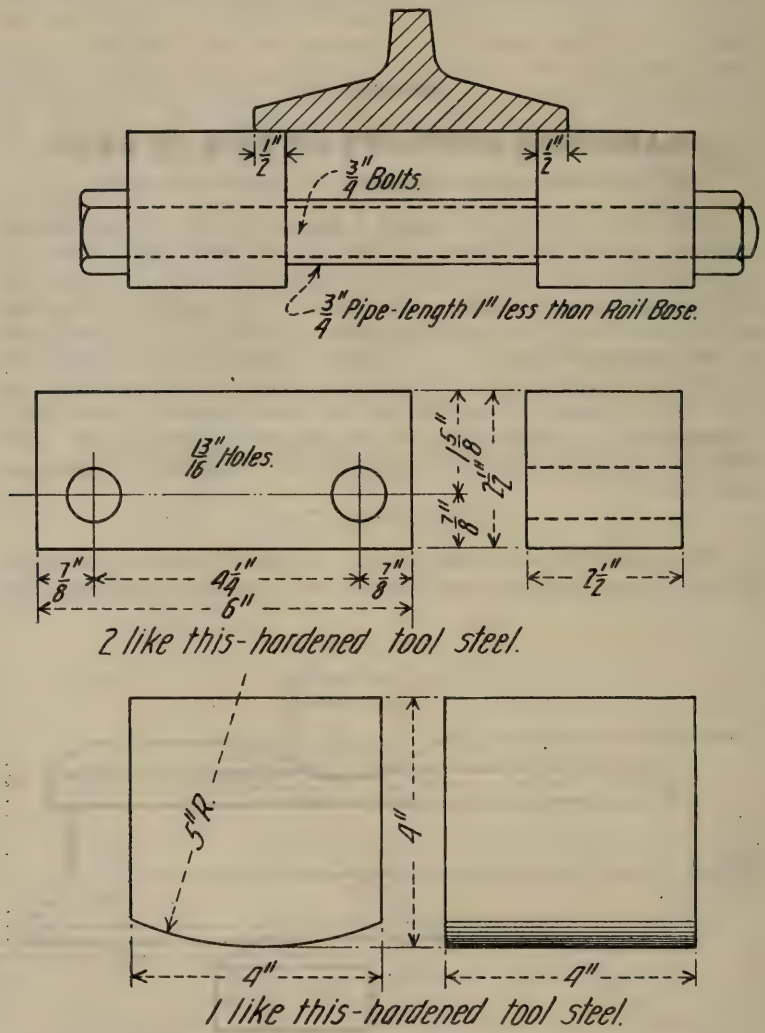


FIG. 2—BLOCKS AND DIE USED IN TRANSVERSE TEST OF BASE.

BESSEMER RAILS.

Specimens of titanium-treated Bessemer rails were tested from one rail-bar from each of five heats, by cutting off a two-foot piece from the head end of each of the four rails of each bar, thus making 20 pieces in

all. After blowing the iron, the spiegel was added to the converter, held 2½ minutes, and then poured into the teeming ladle, ferro-titanium equivalent to .1 per cent. of metallic titanium being added at the same time in the form of a cold 15 per cent. alloy. The steel was then held 3 minutes in the ladle and finally poured into iron molds. The ingots were rolled into 85-lb. A. S. C. E. section rails in 6 blooming passes, 4 roughing passes and 5 finishing passes, or a total of 15 passes from the ingot to the rail. Each ingot made four rails and the pieces for test were cut off at the hot saw and placed on their heads to cool.

The heats represented by the samples and the carbon and manganese determinations on the ladle samples of these heats were as shown in table 1. The heats were made May 8, 1912.

TABLE 1—ANALYSIS OF BESSEMER HEATS.

Heat Number.	Carbon.	Manganese.
9774	.48	.88
9776	.52	.87
7781	.52	.81
9782	.52	.90
9784	.51	.80

Individual heat determinations were not made on the other elements, but according to the results on average samples, they were about as follows: Phosphorus, .092 per cent.; sulphur, .093 per cent; silicon, .13 per cent.

The results of the transverse base tests of these rails are given in table 2. The load represents the number of pounds that it took to break the base of the rail. The transverse elongation was measured by putting a prick punch mark on the center line of the base and then marking

TABLE 2—TRANSVERSE BASE TESTS, BESSEMER RAILS.

No.	Load. Lbs.	Transverse elongation. Per cent.	Distance of break from center. Inches.	Sag of unbroken flange. Inches.	Length of break at flange. Inches.	Surface seam.
9774A	145,600	1	.89	.13	12.5	None
B	174,000	3	.52	.22	14.3	None
C	165,600	2	.30	.13	17.2	Small
D	128,000	0	1.00	.04	12.5	None
9776A	137,500	1	.80	.12	12.0	None
B	151,400	1	.53	.13	14.7	None
C	165,000	3	.02	.21	20.0	Small
D	112,000	0	.50	.02	Straight	.08

No.	Load. Lbs.	Transverse elongation. Per cent.	Distance of break from center. Inches.	Sag of unbroken flange. Inches.	Length of break at flange. Inches.	Surface seam.
9781A	136,000	2	.71	.09	11.5	None
B	159,900	4	1.00	.31	12.0	None
C	166,000	5	1.20	.43	9.7	None
D	142,400	3	.02	.23	Straight	Small
9782A	147,700	3	.30	.22	14.8	None
B	152,900	2	.04	.22	19.0	.02
C	124,000	1	.31	.08	14.0	.04
D	129,000	1	.57	.09	11.0	None
9784A	150,300	3	.46	.20	13.5	None
B	170,800	4	.60	.34	13.0	None
C	162,100	3	.10	.26	16.0	Small
D	168,100	5	.72	.34	11.3	None

two one-inch spaces on each side of this crosswise on the bottom of the base and at the middle of the length of the piece tested. These spaces were measured after breaking the base, and the greatest extension in any one of the four spaces was taken as the measure of transverse ductility. The distance of the break from the center is the distance from the middle punch mark to the fracture. The sag of the flange not broken is the distance from a straight edge laid on the bottom of the base near the

Fig. 3—Samples of Bessemer Rails After Test—Bottom View.

edge of the unbroken flange to the flange where bent most from the straight surface of the base. The length of the break was measured where it came out to or near to the edge of the flange. Under the column

FIG. 4—SAMPLES OF BESSEMER RAILS AFTER TEST—SIDE VIEW.

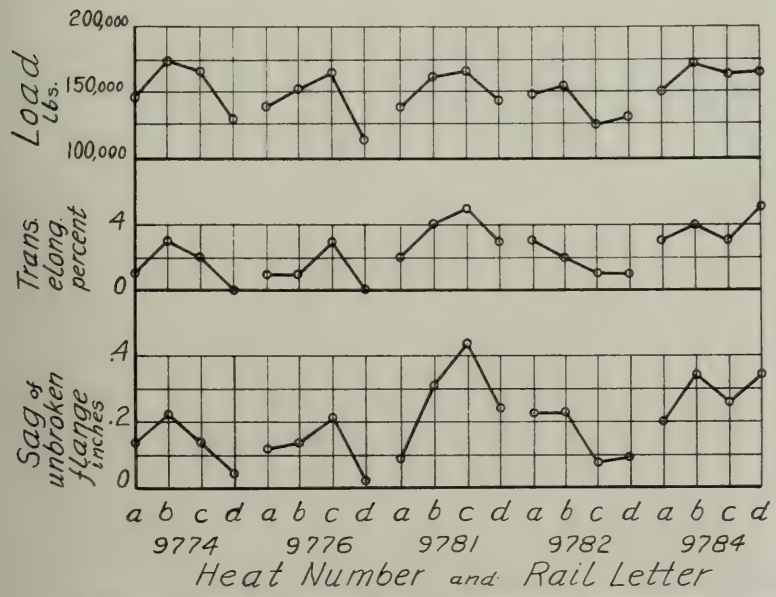


FIG. 5—PLOTTED RESULTS SHOWING LOAD, TRANSVERSE ELONGATION AND SAG OF FLANGE OF BESSEMER RAILS.

"surface seams" is shown whether a seam at the surface showed in the fracture, and its depth.

The various types of fractures obtained in this test as viewed from the bottom of the rail are presented in Fig. 3, which shows eight of the rails after test. It will be noted that some of the breaks were short cres-

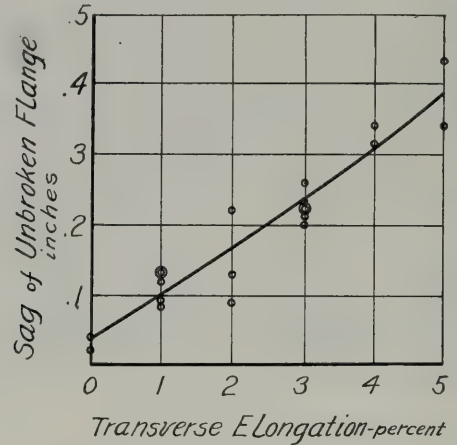


FIG. 6—TRANSVERSE ELONGATION PLOTTED IN RELATION TO SAG OF FLANGE, BESSEMER RAILS.

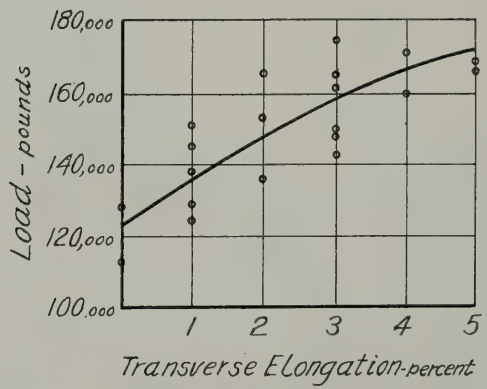


FIG. 7—TRANSVERSE ELONGATION PLOTTED IN RELATION TO LOAD, BESSEMER RAILS.

cent-shaped, others were long crescent-shaped, while two of them were straight cracks. A side view of these rails is shown in Fig. 4, showing the side not broken so the sag of the unbroken flange may be seen.

In order that the main results may be compared more conveniently,

the load, the transverse elongation and the sag of the flange are plotted in Fig. 5. It will be noted that these items in a general way increase or decrease together. This is more definitely shown in Fig. 6, in which the transverse elongation is plotted in relation to the sag of the unbroken flange, and in Fig. 7, in which the elongation is plotted in relation to the load which was required to break the rail. The curves in these figures show that the transverse elongation increases as the sag increases and at a slightly decreasing rate within the limits of these results. The elongation also increases as the load increases, but at a slightly increasing rate. The transverse elongations at the bottom of the base ranged from 0 to 5 per cent., with most of them ranging between 1 and 3 per cent., inclusive. The sag of the base ranged from .02 to .43 in., with most of the results ranging from about .10 to .25 in.

OPEN-HEARTH RAILS.

Base tests were made of the entire rail-bar, cut into 2-ft. pieces, from one ingot of open-hearth steel rolled into 100-lb. rail of the Dudley section. (See Proc. Am. Ry. Engrg. & M. W. Assoc., Vol. 12, part 2, 1911, page 146.) The steel was basic open-hearth steel, heat 3705, made May 14, 1912, and the rolling was similar to that already described for the Bessemer rails. The ladle analysis gave the following results: Carbon, .63; phosphorus, .015; sulphur, .044; manganese, .97; silicon, .15. The top bloom crop was made as small as practicable to allow of rolling, and thus a large part of the usual top discard was included in the test, and after rolling the bar was cut into four pieces, marked A, B, C and D, in order from the top end of the ingot, no rail butts being cut off the ends of the bar. The weights of bloom crops and rails and the lengths of the rails were as shown in table 3.

TABLE 3—WEIGHTS AND LENGTHS, O. H. STEEL.

	Weight, lbs.	Length, ft.	in.
Bloom crop, top	72		
A rail	1,194	35	7¾
B rail	1,114	33	4
C rail	725	21	8⅛
D rail	848	25	11
Bloom crop, bottom	150		
Weight of ingot	4,103		

The distance of the middle of each piece from the top of the ingot, figured in pounds and in per cent., is shown in table 4. The results of the tests are shown in table 5, and the headings of the various columns have the meanings already explained. The column "side broken" refers to whether it was the top or bottom flange as rolled that broke.

TABLE 4—TEST PIECES, OPEN-HEARTH.

No.	Lbs.	Per cent.	No.	Lbs.	Per cent.	No.	Lbs.	Per cent.	No.	Lbs.	Per cent.
A 1	105	2.6	B 1	1,299	31.7	C 1	2,413	58.8	D 1	3,138	76.5
2	172	4.2	2	1,366	33.3	2	2,480	60.5	2	3,205	78.1
3	239	5.8	3	1,433	35.0	3	2,547	62.1	3	3,272	79.8
4	305	7.4	4	1,499	36.6	4	2,613	63.7	4	3,338	81.4
5	372	9.1	5	1,566	38.2	5	2,680	65.3	5	3,405	83.0
A 6	439	10.8	B 6	1,633	39.8	C 6	2,747	67.0	D 6	3,472	84.6
7	505	12.3	7	1,699	41.4	7	2,813	68.6	7	3,538	86.3
8	572	13.9	8	1,766	43.0	8	2,880	70.3	8	3,605	88.0
9	639	15.6	9	1,833	44.7	9	2,947	71.9	9	3,672	89.6
10	705	17.2	10	1,899	46.3	10	3,013	73.5	10	3,738	91.2
A11	772	18.8	B11	1,966	47.9	C11	3,080	75.1	D11	3,805	92.8
12	839	20.4	12	2,033	49.5	..	.....	....	12	3,872	94.4
13	905	22.1	13	2,099	51.2	..	.....	....	13	3,938	96.0
14	972	23.7	14	2,166	52.8	..	.....	....	..	.....	....
15	1,039	25.3	15	2,233	54.4	..	.....	....	..	.....	....
A16	1,105	26.9	B16	2,299	56.0	..	.....	....	..	.....	....
....	.....	....	17	2,366	57.7	..	.....	....	..	.....	....

TABLE 5—TRANSVERSE BASE TEST, O. H. RAILS.

No.	Per cent. from top.	Load, lbs.	Trans. elong., per cent.	Break from center, inches.	Side broken.	Break at flange, inches.	Sag of unbroken flange, inches.	Surface seams.
A 1	2.6	145,300	0	1.53	Top	9.3	.02	None
2	4.2	156,400	1	.74	Bot.	13.0	.07	None
3	5.8	170,400	1	.87	Top	14.0	.07	None
4	7.4	134,000	1	.77	Bot.	12.8	.03	None
5	9.1	109,300	0	.60	Bot.	14.0	.01	None
6	10.8	177,000	1	.57	Bot.	12.5	.10	None
A 7	12.3	175,000	1	.74	Top	11.8	.06	None
8	13.9	173,000	1	1.20	Top	11.3	.08	None
9	15.6	106,000	0	.78	Bot.	13.0	.01	None
10	17.2	159,600	0	1.15	Top	10.4	.05	None
11	18.8	172,000	1	.87	Bot.	13.5	.07	None
12	20.4	.....	1	.24	Bot.	10.0	.07	None
A13	22.1	195,200	2	1.47	Top	9.8	.09	None
14	23.7	166,700	1	.71	Bot.	14.0	.06	None
15	25.3	197,000	2	1.00	Bot.	13.5	.11	None
16	26.9	189,700	1	1.27	Top	9.8	.09	None

No.	Per cent. from top.	Load, lbs.	Trans. elong., per cent.	Break from center, inches.	Side broken.	Break at flange, inches.	Sag of unbroken flange, inches.	Surface seams.
B 1	31.7	188,100	1	.77	Bot.	13.8	.11	None
2	33.3	198,500	1	.01	Top	12.0	.10	None
3	35.0	200,400	1	1.00	Top	11.0	.11	None
4	36.6	202,900	1	.75	Top	12.5	.11	None
5	38.2	211,200	2	.83	Bot.	12.0	.18	None
6	39.8	206,900	2	1.22	Top	9.8	.15	None
B 7	41.4	.....	1	.21	Both	18.1	...	None
8	43.0	152,000	1	.35	Bot.	16.8	.03	Small
9	44.7	194,900	1	.97	Top	10.8	.09	None
10	46.3	179,000	1	.59	Bot.	14.3	.07	None
11	47.9	221,900	2	.78	Top	10.5	.21	None
12	49.5	209,100	2	.93	Bot.	13.0	.15	None
B13	51.2	213,000	2	.83	Bot.	13.4	.18	None
14	52.8	179,000	1	.51	Bot.	13.6	.08	None
15	54.4	209,200	1	.59	Bot.	16.3	.18	None
16	56.0	217,700	2	.98	Bot.	10.5	.18	None
17	57.7	184,800	1	1.01	Bot.	11.8	.09	None
C 1	58.1	199,200	2	.06	Both	12.9	...	None
2	60.5	146,000	1	.70	Bot.	13.4	.03	None
3	62.1	216,300	3	.67	Bot.	14.4	.21	None
4	63.7	199,000	2	.62	Bot.	14.6	.11	Small
5	65.3	219,600	2	1.00	Top	9.8	.17	None
6	67.0	205,000	2	.56	Bot.	13.3	.13	Small
C 7	68.6	212,200	2	.14	Both	18.7	.16	Small
8	70.3	195,500	2	.32	Top	15.0	.11	None
9	71.9	207,300	2	.14	Top	19.0	.13	None
10	73.5	205,000	2	1.19	Top	9.6	.17	None
11	75.1	207,800	2	.99	Top	12.0	.16	None
D 1	76.5	207,900	2	.92	Top	10.0	.13	None
2	78.1	207,500	2	.34	Top	12.3	.19	None
3	79.8	205,400	2	.92	Top	10.1	.15	None
4	81.4	218,400	3	1.05	Top	10.4	.22	None
5	83.0	209,200	2	1.02	Bot.	10.7	.21	None
6	84.6	129,000	0	.06	Top	15.8	.02	.03
D 7	86.3	196,000	2	1.42	Bot.	9.5	.07	None
8	88.0	175,800	1	1.43	Bot.	9.5	.09	None
9	89.6	202,900	2	1.35	Bot.	9.4	.15	None
10	91.2	203,100	1	1.46	Bot.	10.0	.18	None
11	92.8	187,000	1	.46	Top	15.1	.08	None
12	94.4	172,400	2	.10	Bot.	17.0	.07	None
13	96.0	197,200	2	.57	Top	15.0	.28	None

Some typical samples of the open-hearth rails after testing are shown in Fig. 8, which gives a bottom view of the pieces, and in Fig. 9, which gives a side view, showing the unbroken flanges.

The results showing the load, the transverse elongation and the sag of the flange are plotted in Fig. 10, in relation to the distance from the

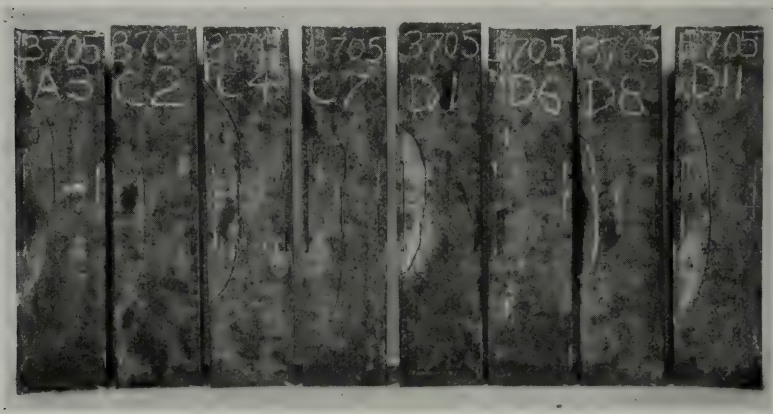


Fig. 8—Samples of Open-Hearth Rails After Test—Bottom View.

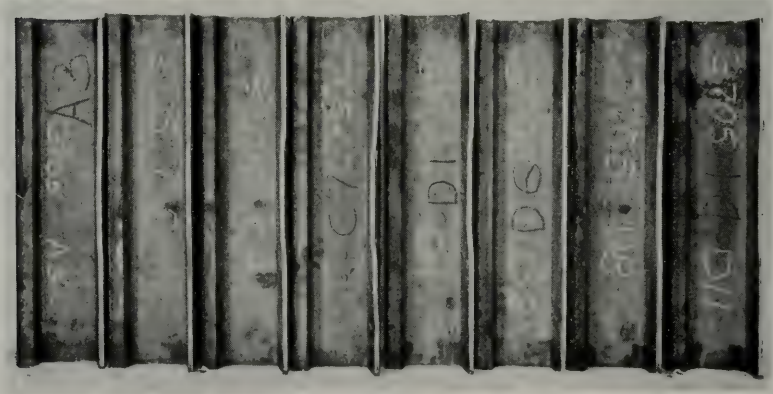


Fig. 9—Samples of Open-Hearth Rails After Test—Side View.

top of the ingot. It will be noted that the upper 20 per cent. or so of the ingot showed less strength of base and less transverse ductility of the base in this kind of test than the rest of the bar, and the part of the bar between 60 and 80 per cent. down showed a little the best results. In this steel, also, the strength and ductility varied together in a general way. Although most of the low results were in the upper part of the

bar there were some low results distributed along the rest of the bar. The transverse elongation in this steel varied from 0 to 3 per cent., most of the results being 1 or 2 per cent. The sag of the flange varied from .01 to .22 in., averaging about .12 in., although the results varied considerably.

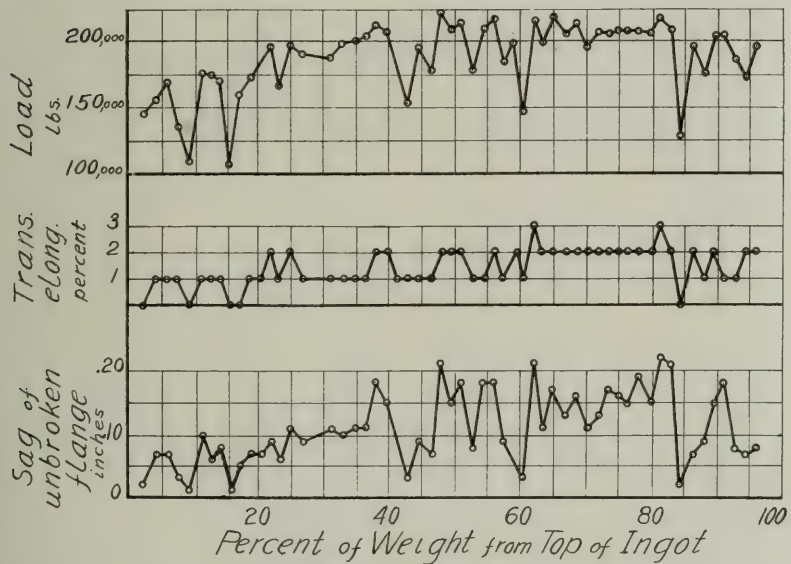


FIG. 10—PLOTTED RESULTS SHOWING LOAD, TRANSVERSE ELONGATION AND SAG OF FLANGE OF OPEN-HEARTH RAILS.

SUMMARY.

1. A description is given of a method for determining the transverse ductility of the bottom of the base of a rail and the load required to break the base of the rail supported near the edges of the flanges. The results of a few tests made at Buffalo at the works of the Lackawanna Steel Co. of Bessemer and open-hearth rails, are recorded.

2. The method of making the tests was to support a piece of rail about 2 ft. long on two supports placed opposite each other near the edges of the flanges under the middle of the length of the rail. The supports were 6 in. long and placed one-half inch in from the sides of the flanges. The load was applied in the test machine to the top of the rail at the middle.

3. In a few tests of titanium-treated Bessemer 85-lb. A. S. C. E. rails, the transverse elongation at the bottom of the base varied from 0 to 5 per cent., with most of the results between 1 and 3 per cent. inclusive. The sag of the base ranged from .02 to .43 in., with most of the results

between .10 and .25 in. The loads varied from 112,000 lbs. to 174,000 lbs., with most of them in the neighborhood of 150,000 lbs.

4. The entire rail-bar from one open-hearth ingot rolled in 100 lbs. Dudley section rails, was tested, and gave transverse elongations varying from 0 to 3 per cent., with most of the results showing 1 or 2 per cent. The sag of the flange varied from .01 to .22 in., averaging about 12 in. The load varied from 106,000 lbs. to 221,900 lbs., most of the results being in the neighborhood of 200,000 lbs.

Appendix F.

INFLUENCE OF SEAMS OR LAMINATIONS IN BASE OF RAIL ON RAIL FAILURES

By H. B. MacFarland, Engineer of Tests, A. T. & S. F. Ry. System, Topeka, Kan.

During the months of February and March, 1912, 277 failed rails were received in the laboratory at Topeka, Kan., for test. A classification of these rails according to the nature of the failures is shown in table 1.

TABLE 1.—FAILURES CLASSIFIED.

	DATE RAIL LAID.			
Nature of Failure.	Before 1907.	1907 and Later.	Date Not Given.	Total.
Head	39	29	8	76
Web (end or center)	4	5	0	9
Base only (half-moon)	19	2	1	22
Square or angle, accompanied by half-moon base fracture	81	38	3	122
Others	7	1	3	11
End	26	8	3	37
Total	176	83	18	277

It will be seen that 64 per cent. of the total number of failed rails received were laid before the year 1907. Thirty per cent. were laid within the last five years. Six per cent. of the rails received were without sufficient identification to determine the length of time in track.

It is to be noted that of the broken rails received, the largest per cent. of failures were from or accompanied by base fractures of a characteristic half-moon shape. Twenty-two of the rails received had failed from this characteristic base fracture, and 122 of the 133 rails which failed with square or angular breaks, were accompanied by the half-moon base fractures. One hundred and forty-four, or 52 per cent. of the 277 failed rails received then, showed a characteristic half-moon fracture of the base. This is a decided increase in base failures over broken rails received in any previous months. During the month of January only nine per cent. of the failed rails received were of this class of failure.

Figures 1, 2 and 3 illustrate the characteristic half-moon base fractures accompanying the square and angular breaks.

A further classification of the failed rails with the characteristic half-moon base fractures according to manufacturers is shown in table 2.

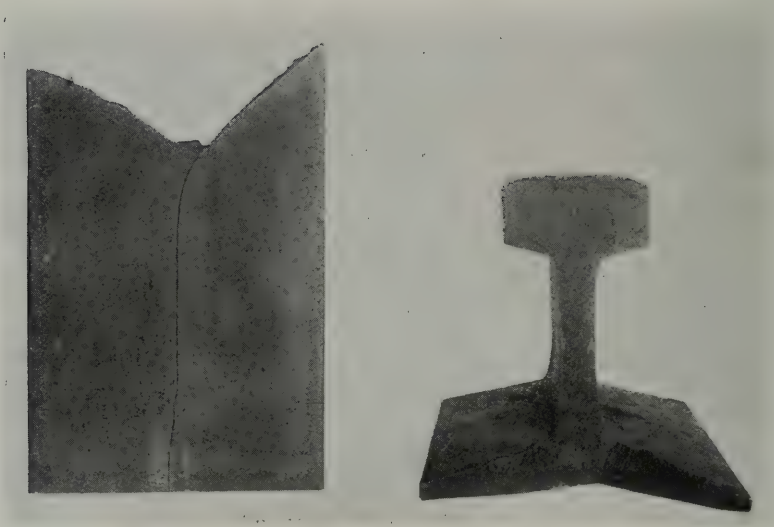


FIG. 1—RAIL 10168, FAILED IN SERVICE, ILLUSTRATING THE CHARACTERISTIC HALF-MOON BASE FAILURE. NOTE THE FISSURE RUNNING FROM THE BASE TOWARD THE WEB IN THE CROSS-SECTION ON THE RIGHT.

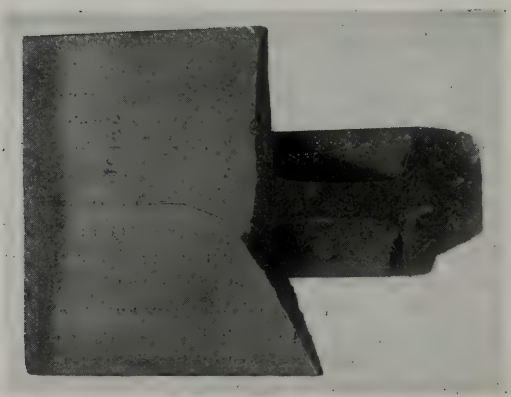


FIG. 2—SHOWING RAIL 10158, FAILED IN SERVICE WITH ANGULAR BREAK, PRECEDED BY HALF-MOON BASE FAILURE.

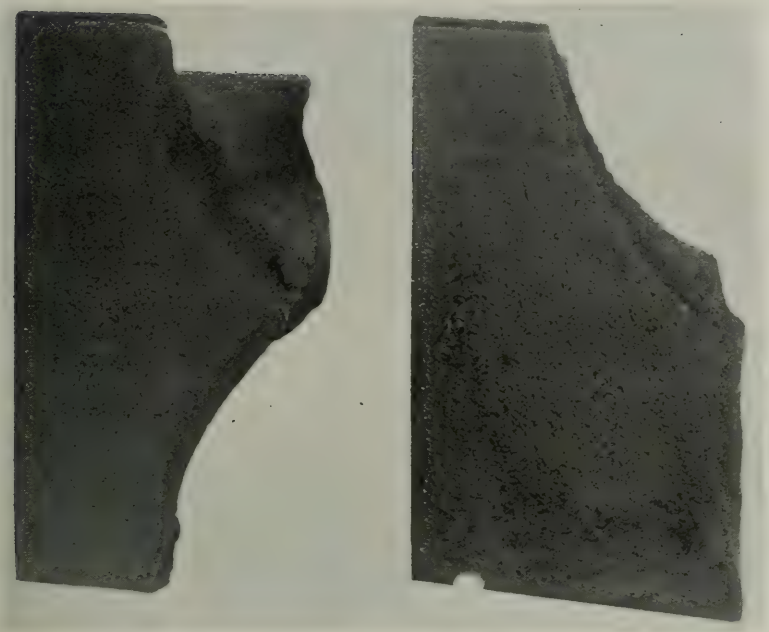


FIG. 3—RAIL 11378 ON LEFT AND RAIL 11369 ON RIGHT, FAILED IN SERVICE, WITH SQUARE OR ANGULAR BREAKS PRECEDED BY CHARACTERISTIC HALF-MOON BASE FAILURES.

TABLE 2.—HALF-MOON FRACTURES CLASSIFIED.

Manufacturer.	Number.	Per Cent.
Illinois Steel Co.—		
South Works	95	66.0
Gary Works	1	0.7
Maryland Steel Co.	29	20.0
Cambria Steel Co.	8	5.6
Bethlehem Steel Co.	1	0.7
Colorado Fuel & Iron Co.	6	4.2
Name not given	4	2.8
Total	144	100.0

An examination of the rails which had failed with square or angular breaks accompanied by a half-moon fracture of the base, apparently indicated that the ultimate failure of the rail had been preceded by the fracture of the base. The predominance of these half-moon base failures led to undertaking an investigation on the failed rails in question in an endeavor to determine the causes leading up to the fracture of the rail.

INVESTIGATIONS.

The high percentage of base failures indicated possible inherent defects in the quality of the material in the base of the rail. It was accordingly decided to first investigate the material in the base of the rail as compared with the web and head to determine whether or not there was a lack of uniformity in the quality of the material throughout the section of the rail.

Twenty-two rails showing characteristic base failures were selected, and three tensile specimens secured from each. The "A" specimen was secured from the flange side of the head of the rail; the "B" specimen from the joint of the head and the web; and the "C" specimen from the joint of the base and the web. The specimens were taken running longitudinally

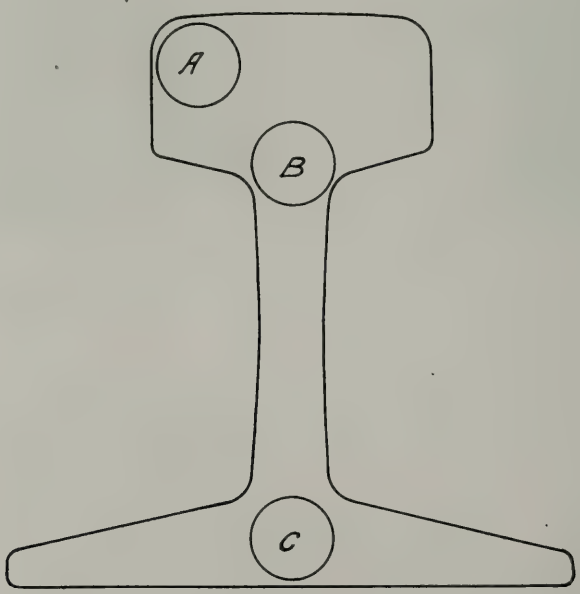


FIG. 4—LOCATIONS OF TENSILE SPECIMENS.

with the rail. Figure 4 illustrates the position from which the different tensile specimens were secured in the cross section. The results of the tensile tests are presented in tables 3 and 4.

From results of these tensile tests it will be seen that the variation in the characteristics of the metal in the base, web and head of the rails is so slight as to be practically negligible.

A close study of the failed rails showing the characteristic half-moon base fractures indicates that the ultimate failure of the rails is preceded

TABLE 3—TENSILE TESTS—ULTIMATE STRENGTH AND ELASTIC LIMIT OF 22 RAILS SHOWING BASE FAILURES, FEBRUARY AND MARCH, 1912.

Laboratory Rail No.	Ultimate Strength, Pounds per Square Inch. A	B	C	Elastic Limit, Pounds per Square Inch. A	B	C
10,086	117,200	111,800	114,500	61,200	57,900	59,400
10,088	107,500	117,000	103,700	60,400	57,900	50,800
10,090	121,500	113,200	121,500	64,400	70,400	65,700
10,093	119,700	113,500	114,000	72,000	63,900	60,900
10,094	120,300	111,000	118,200	68,200	59,700	65,700
10,097	111,700	124,500	113,700	70,500	71,800	68,500
10,113	122,500	114,700	123,000	73,000	63,900	68,000
10,128	121,000	111,800	123,300	60,900	60,900	71,100
10,129	121,800	114,000	122,200	66,200	59,100	66,000
10,157	118,500	107,800	117,500	66,000	60,100	63,700
10,158	129,000	119,000	128,000	76,400	64,700	71,600
10,168	122,000	114,900	122,300	66,200	61,700	66,000
11,294	137,400	130,000	133,000	73,000	67,800	66,300
11,298	122,800	111,500	119,400	70,200	58,000	66,000
11,328	103,500	94,400	101,000	64,400	52,900	51,000
11,333	123,000	114,000	120,700	67,900	57,800	68,500
11,369	128,700	123,400	126,600	76,200	66,000	68,500
11,378	130,500	128,500	131,000	72,100	69,800	72,300
11,382	131,600	118,600	.....	71,000	63,700	.....
12,089	118,900	119,700	121,000	63,700	56,100	63,400
17,038	131,300	134,200	131,400	68,200	75,200	75,400
17,040	125,400	115,800	122,200	70,500	60,400	68,800
Average..	122,100	116,500	120,390	68,300	62,700	65,600

TABLE 4—TENSILE TESTS—ELONGATION AND REDUCTION OF AREA OF 22 RAILS SHOWING BASE FAILURES, FEBRUARY AND MARCH, 1912.

Laboratory Rail Number.	Per Cent. Elongation in 2 Inches. A	B	C	Per Cent. Reduction in Area. A	B	C
10,086	16.5	18.0	15.0	31.4	30.3	27.0
10,088	17.5	12.5	17.0	30.3	20.0	23.5
10,090	16.0	2.5	13.5	25.2	3.5	16.0
10,093	14.0	19.0	17.0	31.9	35.2	33.7
10,094	16.0	17.0	17.0	30.0	33.3	27.3
10,097	4.0	4.0	5.0	3.2	7.4	6.4
10,113	14.0	16.5	16.5	25.5	28.2	25.8
10,128	17.0	19.0	15.5	30.4	33.7	28.4
10,129	17.0	18.5	16.5	30.1	32.8	27.7
10,157	16.5	20.0	19.0	33.0	34.4	30.1
10,158	15.5	16.5	15.0	26.4	30.1	26.3
10,168	15.5	18.5	16.0	28.4	32.1	27.3
11,294	13.0	13.5	12.0	23.4	22.5	21.2
11,298	15.5	19.0	16.0	27.8	34.0	29.0
11,328	18.0	24.0	22.0	38.1	39.2	38.2
11,333	15.0	17.5	15.0	26.9	28.2	24.4
11,369	15.0	16.0	20.0	28.0	25.3	27.0
11,378	14.5	6.5	13.5	24.5	5.5	20.4
11,382	14.5	5.0	....	24.3	3.9	....
12,089	15.0	16.0	14.5	19.7	22.5	20.0
17,038	13.5	6.5	12.0	20.7	5.4	15.4
17,040	15.0	17.0	15.0	25.6	29.6	24.3
Average.....	14.9	14.7	15.4	26.6	21.0	24.7

by the failure of the base, which indicates that the rail base as rolled is initially weak and gives away first under conditions of service.

A preliminary investigation was accordingly undertaken to determine with what loading a section of rail would fail through the base when supported on edges and placed in the testing machine, loads being applied on the head. To determine the amount of loading required short sections of rails that had failed in service were placed in the testing machine and supported at the edges of the base and loads were applied on the head of the rail until the base failed.

All of the sections of sufficient length failed with the characteristic half-moon fracture. An examination of these fractures showed seams in the base extending a short distance below the surface of the base of the rails.

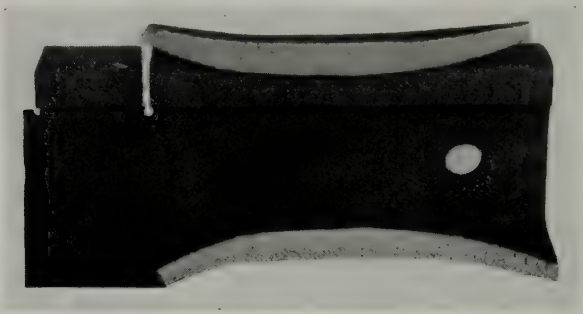


FIG. 5—SHORT SECTION OF NEW RAIL, SHOWING CHARACTERISTIC HALF-MOON BASE FAILURE. BROKEN BY APPLYING LOAD ON HEAD AND SUPPORTING BASE AT EDGES.

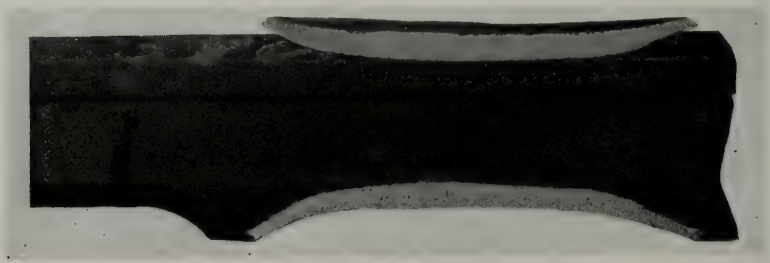


FIG. 6—RAIL 11248. ON LEFT END OF RAIL IS A HALF-MOON BASE FRACTURE DEVELOPED IN SERVICE, AND ON RIGHT END IS A HALF-MOON BASE FRACTURE DEVELOPED IN TESTING MACHINE BY PLACING RAIL ON SUPPORTS 5 IN. LONG, WITH A 4⅛-IN. SPAN AND APPLYING LOAD ON HEAD.

Table 5 shows the results of these tests. Figures 5 and 6 show characteristic failures of these sections and illustrate the seams along the line of fracture.

The results of this preliminary investigation suggested a further investigation along the same lines. Ten rails were selected that had failed in service and which showed square or angular breaks preceded by a half-moon base failure. Three sections were sawed from each of these rails—1 inch, 1¾ inches and 5 inches in length, respectively. The 1-inch specimen was polished and etched, the remaining two sections were broken in the testing machine, being supported at the edges for their entire length and loads applied on the head until they failed through the base. The results of these tests are presented in table 6.

Figures 7, 8, 9, 10, 11 and 12 show typical failures of these short specimens as developed in test as well as deep laminations in the base of the etched specimen. The manner in which the line of failure of the sections immediately adjacent to the etched section invariably followed the lines of lamination in the base is very clearly shown.

The curves in figure 13 have been prepared from results obtained in this series of tests and indicate the probable weakening effect on the strength of the rail due to a seam or fissure in the base of the rail.

The results obtained by breaking the sections of rails as given in table 6 indicated that a seam in the base had a marked weakening influence on the strength of the base. This is also borne out by the curves in figure 13. It will be seen that there are two variables here, one the difference in depth of metal at point of failure, and the other the probable difference in quality of metal in the various rails.

In order to overcome these variables and secure results that would be comparable, several sections of the base of one rail were secured and planed to approximately the same thickness. These various sections were approximately 0.4 of an inch in thickness and two inches in length.

The sections were placed in the testing machine with supports at edges, four inches apart and loaded as a beam at the center until they failed. These sections were broken some with base up and some with base down in order to present different conditions of stress in the metal around the seam in the base, i. e., in tension and in compression. Sections were tested with various conditions of surface as well, i. e., with the base planed off so as to remove all seams and present a regular surface; with the original seams in the base as developed in service, and with the base nicked to various depths after being planed.

The results of these tests are shown in tables 7 and 8, and are presented in the form of a curve in figure 14, showing the per cent. reduction in strength relative to per cent. depth of nick or seam of section of the fracture.

Figures 15, 16 and 17 are presented, showing characteristic fractures of small base sections taken from rail numbers 10183, 12091 and 13004. These sections are arranged in the figures in same relative position as broken in machine.

TABLE 5—SHOWING LOADS REQUIRED TO BREAK BASE OF RAILS WITH RAILS SUPPORTED AT EDGES OF BASE.

Specimen No.	Laboratory No.	Section.	Length of Rail, Inches.	Span, Inches.	Length Support, Inches.	Length of Break, Inches.	Total Load, Pounds.	Load Per Inch, 4-Inch Span.	Remarks.
1	14,033	85-lb. ASCE	6.5	4½	2⅜	6.5	50,000	8,670	Seam in base, straight break.
2	10,127	85-lb. ASCE	15.5	4½	2⅜	15.5	(68,050)	4,950	Seam in base, had to reset to
							(70,130)	5,740	finish break.
3	A-11,356	85-lb. ASCE	25.0	4½	2⅜	5.8	70,000	13,500	Half-moon out of base, center.
	B-11,356	85-lb. ASCE	25.0	4½	2⅜	4.0	34,000	9,560	Break half-moon, partly old.
	C-11,356	85-lb. ASCE	25.0	4½	2⅜	9.0	75,000	9,380	Half-moon from end.
4	A-10,123	85-lb. ASCE	36.0	4½	2⅜	9.5	65,000	7,700	Half-moon.
	B-10,123	85-lb. ASCE	36.0	4½	2⅜	14.4	55,000	4,300	Half-moon, start at free end.
5	14,011	90-lb. SF	4.6	4½	2⅜	4.6	78,000	19,060	Straight break on seam.
6	15,009	90-lb. SF	1.8	4½	2⅜	1.8	46,750	28,100	Straight break on seam.
7	62,112	90-lb. SF	1.8	4½	2⅜	1.8	37,340	23,640	Straight break on seam.
8	32,007	90-lb. SF	21.0	4⅛	5	12.0	155,000	13,300	Half-moon, fine seam base
9	90	90-lb. SF	5.6	4⅛	5	5.6	125,000	23,000	Straight break, fine seam.
10	11,280	85-lb. ASCE	18.0	4⅛	5	16.3	50,000	3,170	Slight half-moon, deep seam.
11	12,089	90-lb. SF	30.0	4	5	23.0	90,000	3,900	Straight break, ⅛-in. seam.
12	11,253	85-lb. ASCE	46.0	4½	5	16.2	85,000	5,900	Half-moon, deep seam.
13	10,121	90-lb. SF	38.0	4	5	10.0	105,000	10,500	Half-moon, fine seam.
14	11,248	85-lb. ASCE	22.0	4⅛	5	12.5	115,000	9,500	Half-moon, fine seam.
15	New rail	90-lb. SF	21.0	4⅜	5	10.5	115,500	12,000	Half-moon, deep seam.
16	New rail	90-lb. SF	21.0	3⅞	5	11.0	180,000	15,850	Half-moon, fine seam.

TABLE 6—SHOWING LOADS REQUIRED TO BREAK BASE OF SHORT SECTIONS OF RAILS WITH SECTIONS SUPPORTED AT EDGES OF BASE FOR ENTIRE LENGTH.

Specimen No.	Laboratory No.	Section.	Span, Inches.	Length of Break, Inches.	Width of Break, Inches.	Depth of Seam, Inches.	Per Cent. Seam of Break.	Total Load, Pounds.	Load Per Inch, 4-Inch Span.
1	10,128	85-lb. ASCE	4	1.57	0.90	0.08	8.9	18,280	11,700
			4	4.70	0.85	0.08	9.4	44,950	9,570
2	10,129	85-lb. ASCE	4	1.60	0.80	0.06	7.5	19,940	12,460
			3	1.75	0.80	0.08	10.0	28,000	12,000
3	10,157	85-lb. ASCE	4	1.67	0.90	0.04	4.4	25,000	14,970
			4	4.60	0.85	0.01	1.2	68,400	14,880
4	10,158	85-lb. ASCE	4	1.82	0.92	0.05	5.4	22,160	12,180
			4	4.52	0.94	0.45*	48.0	14,220	3,150
5	10,168	85-lb. ASCE	4	1.70	0.80	0.08	10.0	14,000	8,240
			3	2.38	0.80	0.06	7.5	24,970	7,860
6	11,328	85-lb. ASCE	4	1.62	0.85	0.04	4.7	23,640	14,600
			4	4.70	0.80	0.03	3.8	60,780	14,840
7	11,369	85-lb. ASCE	4	1.81	0.80	0.03	3.1	28,360	15,660
			4	4.58	0.80	0.02	2.5	59,590	13,000
8	11,378	85-lb. ASCE	4	1.61	0.80	0.00	0.0	28,450	17,660
			4	4.76	0.80	0.00	0.0	73,310	15,400
9	11,382	85-lb. ASCE	4	1.65	0.65	0.08	12.3	14,400	8,730
10	12,089	90-lb. SF	4	1.67	0.94	0.06	6.4	21,730	13,020
			4	4.70	0.95	0.05	5.3	57,750	12,280

*NOTE.—Old crack.

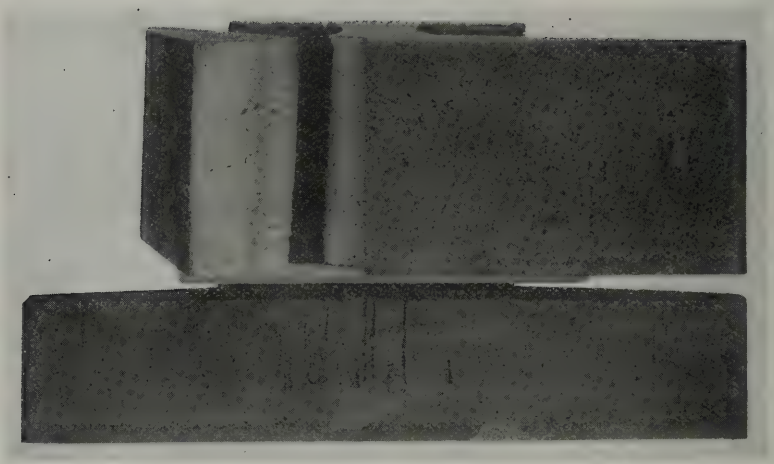


Fig. 7—Rail 10157. Etched Section and Short Section Broken in Testing Machine, Showing Coincidence of Line of Failure with Pronounced Laminations in Base. The Depth of Seam Is Shown on Face of Fracture on the Left.

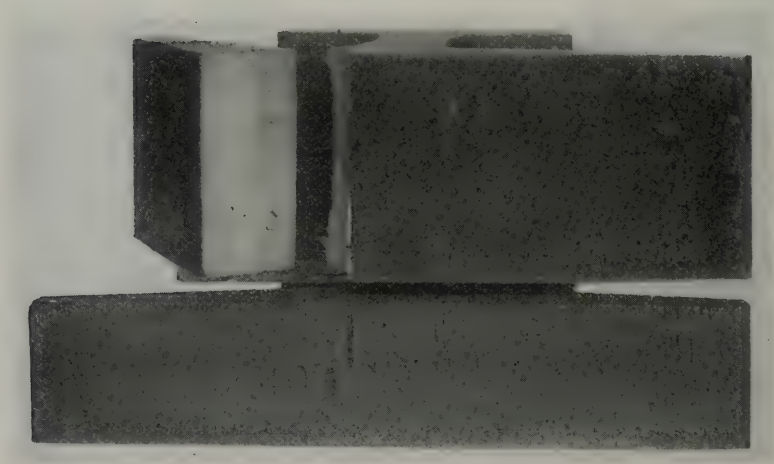


Fig. 8—Rail 10129. Etched Section and Short Section Broken in Test Machine, Showing Coincidence of Line of Failure, with Pronounced Laminations in Base. The Depth of Seam Is Shown on Face of Fracture on the Left.

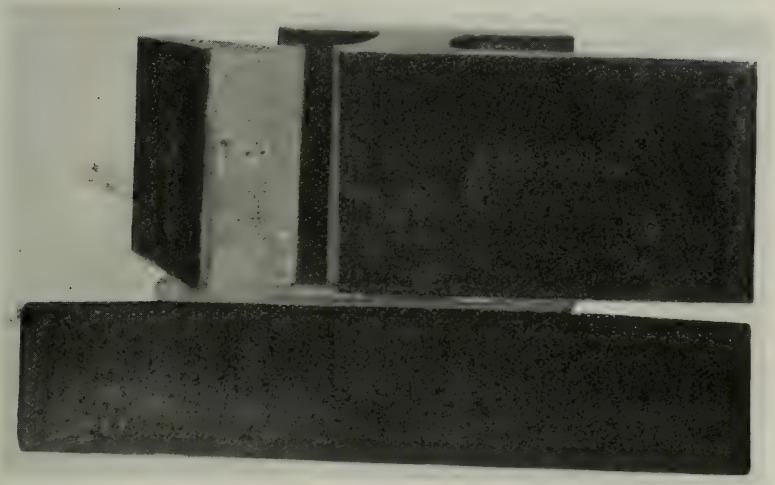


FIG. 9—RAIL 10168. ETCHED SECTION AND SHORT SECTION BROKEN IN TEST MACHINE, SHOWING COINCIDENCE OF LINE OF FAILURE, WITH PRONOUNCED LAMINATIONS IN BASE. THE DEPTH OF SEAM IS SHOWN ON FACE OF FRACTURE ON THE LEFT.

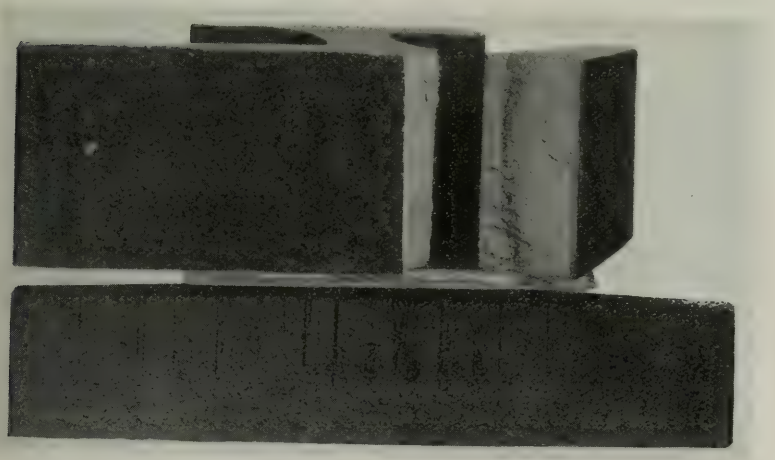


FIG. 10—RAIL 10128. ETCHED SECTION AND SHORT SECTION BROKEN IN TEST MACHINE, SHOWING COINCIDENCE OF LINE OF FAILURE, WITH PRONOUNCED LAMINATIONS IN BASE. THE DEPTH OF SEAM IS SHOWN ON FACE OF FRACTURE ON THE RIGHT.

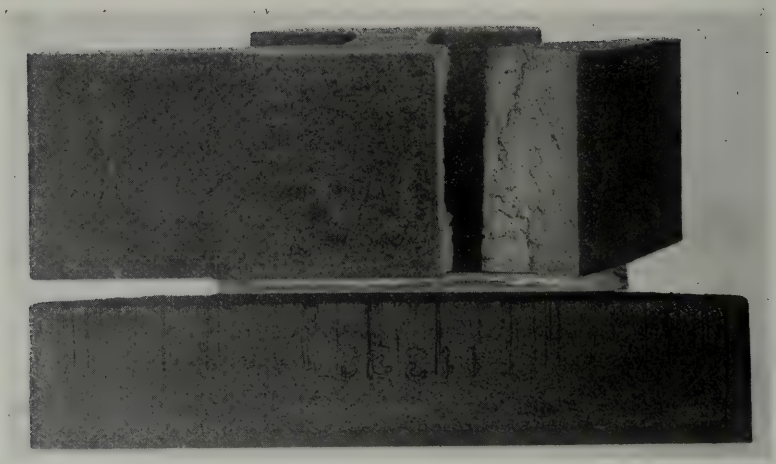


FIG. 11—RAIL 11328. ETCHED SECTION AND SHORT SECTION BROKEN IN TEST MACHINE, SHOWING COINCIDENCE OF LINE OF FAILURE, WITH PRONOUNCED LAMINATIONS IN BASE. THE DEPTH OF SEAM IS SHOWN ON FACE OF FRACTURE ON THE RIGHT.

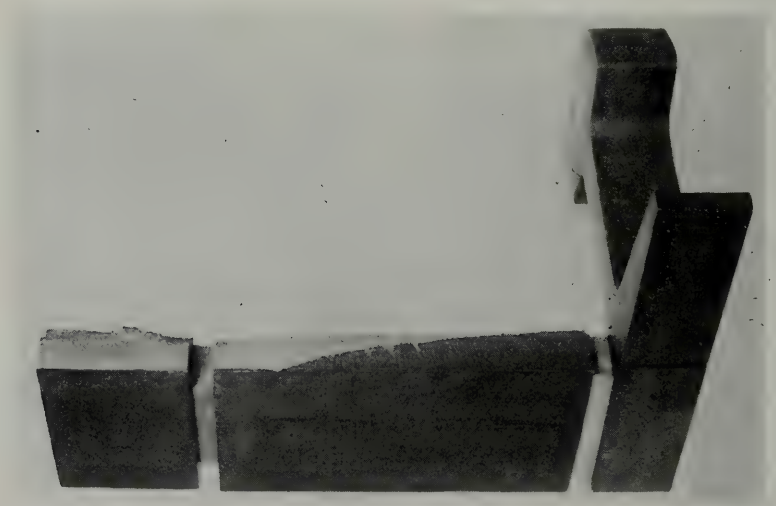


FIG. 12—RAIL 10158. SECTIONS BROKEN IN TEST MACHINE. SECTIONS OF BASE ADJACENT TO ETCHED SECTION, SHOWING COINCIDENCE OF LINE OF FAILURE WITH LAMINATIONS IN BASE. THE SEAM IN THE SECTION AT THE LEFT FOLLOWED THE LINE OF LAMINATION IN THE BASE OF THE ETCHED SECTION. THE DARK AREA IN THE CENTER SECTION INDICATES AN OLD FISSURE IN THE RAIL BASE.

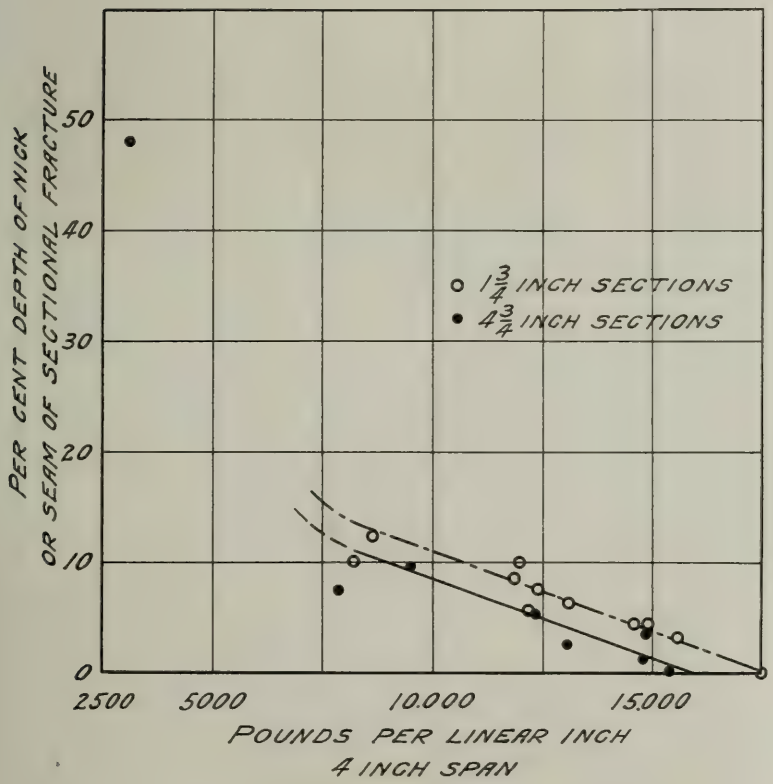


Fig. 13—Breaking Load in Relation to Depth of Nick or Seam in Rail Base.

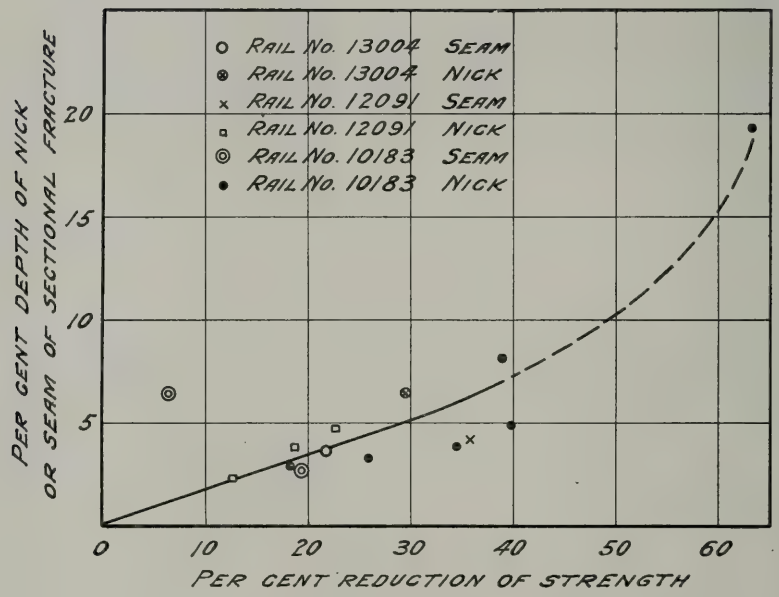


Fig. 14—Reduction of Strength in Relation to Depth of Nick or Seam in Rail Line.

TABLE 7—SHOWING RESULTS OF TESTS OF BASE SECTIONS OF RAILS WITH DIFFERENT SURFACE CONDITIONS.

No.	Size, Inches.	Position of Base in Machine.	Condition of Specimen.	Total Load, Pounds.	Load Per Inch Width, Pounds.	Load Per .4-Inch Thickness, Pounds.	Per Cent. Nick or Seam of Area of Fracture.	Per Cent. Reduction of Strength.
Rail No. 12091:								
1	0.407x1.981	Down	Seam	5,790	2,945	2,810	4.2	35.9
2	0.404x2.010	Up	Planed	8,830	4,405	4,320	0.0	0.0
3	0.409x1.980	Down	Nicked	7,000	3,535	3,380	4.9	22.8
4	0.404x1.975	Down	As rolled	6,970	3,530	3,460	0.0	0.0
5	0.413x2.020	Up	Nicked	8,230	4,070	3,820	2.4	12.8
6	0.415x2.000	Up	Nicked	7,640	3,825	3,555	3.9	18.8
7	0.410x2.015	Down	As rolled	10,710	5,340	5,085	0.0	0.0
8	0.405x2.007	Up	Planed	8,930	4,455	4,440	0.0	0.0
		Average strength per 1-inch by 0.4-inch section, 4,380 pounds.						
Rail No. 13,004:								
1	0.402x2.015	Down	Seam	7,940	3,940	3,900	3.5	21.2
2	0.405x2.001	Up	Planed	10,000	4,975	4,855	0.0	0.0
3	0.403x1.993	Down	Nicked	7,110	3,555	3,500	6.5	29.3
4	0.376x2.001	Down	Planed	8,460	4,225	4,780	0.0	0.0
5	0.350x1.997	Down	Planed	8,030	4,020	5,250	0.0	0.0
6	0.375x1.995	Down	Planed	8,520	4,270	4,860	0.0	0.0
7	0.408x1.998	Down	As rolled	8,140	4,075	3,915	0.0	0.0
8	0.409x1.983	Up	Planed	10,330	5,210	5,000	0.0	0.0
		Average strength per 1-inch by 0.4-inch section, 4,930 pounds.						

TABLE 8—SHOWING RESULTS OF TESTS OF BASE SECTIONS OF RAILS WITH DIFFERENT SURFACE CONDITIONS.

No.	Size, Inches.	Position of Base in Machine.	Condition of Specimen.	Total Load, Pounds.	Load Per Inch Width, Pounds.	Load Per .4-Inch Thickness, Pounds.	Per Cent. Nick or Seam of Area of Fracture.	Per Cent. Reduction of Strength.
Rail No. 10,183:								
1	0.381x1.965	Up	Planed	7,960	4,050	4,460	0.0	0.0
2	0.388x2.000	Down	Seam	6,850	3,425	3,640	2.8	19.3
3	0.384x2.030	Up	Nicked	7,800	3,845	4,170	2.6	18.3
4	0.380x1.985	Up	Nicked	6,730	3,390	3,760	3.2	26.3
5	0.383x1.990	Up	Nicked	6,070	3,050	3,330	3.9	34.7
6	0.383x2.010	Up	Nicked	5,780	2,875	3,140	8.1	38.5
7	0.382x2.005	Up	Planed	10,040	5,010	5,325	0.0	0.0
8	0.362x2.000	Down	Planed	9,050	4,525	5,510	0.0	0.0
9	0.385x1.995	Up	Nicked	3,470	1,740	1,880	19.2	63.2
10	0.389x2.000	Down	Seam	9,030	4,510	4,770	6.4	6.5
11	0.388x2.005	Up	Planed	9,660	4,820	5,125	0.0	0.0
12	0.385x1.985	Up	Nicked	5,600	2,820	3,050	4.9	40.2

Average strength per 1-inch by 0.4-inch section, 5,100 pounds.

FIG. 15—RAIL 10183. SHOWING SURFACES OF FRACTURES OF BASE SECTIONS BROKEN AS BEAMS LOADED AT CENTER AND ON SUPPORTS 4 INS. APART. SECTIONS BROKEN WITH VARIOUS CONDITIONS OF SURFACE: WITH NICKS, WITH SEAMS AND WITH SMOOTH SURFACE TO DETERMINE WEAKENING INFLUENCE OF SEAMS.

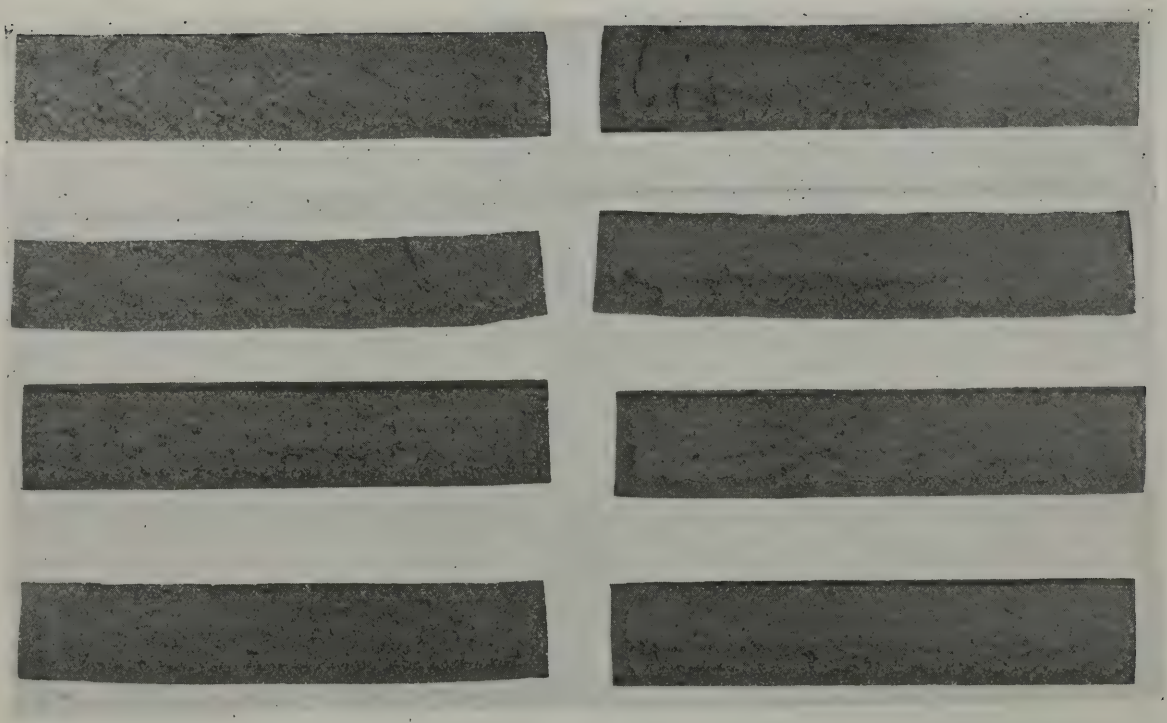


FIG. 16—RAIL 12091 ON LEFT AND RAIL 13004 ON RIGHT, SHOWING SURFACES OF FRACTURES OF BASE SECTIONS BROKEN AS BEAMS LOADED AT CENTER AND ON SUPPORTS 4 INS. APART. SECTIONS BROKEN WITH VARIOUS CONDITIONS OF SURFACE; WITH NICKS, WITH SEAMS AND WITH REGULAR SURFACES TO DETERMINE WEAKENING EFFECT OF SEAMS.

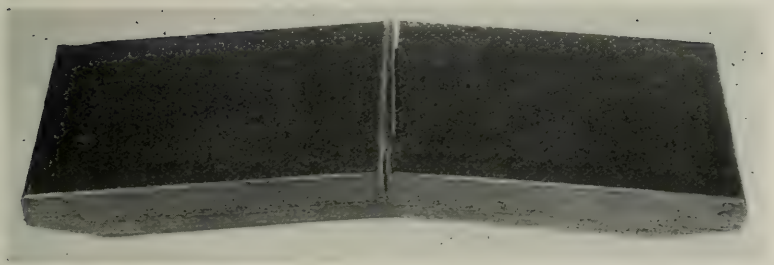


FIG. 17—RAIL 12093, SHOWING FAILURE OF SHORT SECTION OF BASE. RAIL NICKED. IT WILL BE NOTED THAT THE SECTION FAILED ALONG THE LINE OF A SEAM FOR THE GREATER PART OF THE DISTANCE AND THEN JUMPED OVER ALONG THE LINE OF NICKING AT THE EDGE OF THE SECTION.

The depreciation in strength between sections with seams or nicks and the sections with smoothly planed surfaces is readily apparent. The weakening effect of a seam in the base is almost as great as that of a nick of equal depth, indicating that the bond of the metal where these seams are present is more physical than molecular.

This point is well illustrated by the results of tests of sections 4, 5 and 6 of rail No. 13004, as compared with results of tests of specimens 1 and 7. The former specimens had been planed to thicknesses of 0.376, 0.350 and 0.375 inches, respectively, so that the seams had been removed, yet the section is actually stronger than sections 1 and 7, which were 0.402 and 0.408 of an inch in thickness, respectively. Section 1 had a seam in the fracture that was 3.5 per cent. of the total depth of section, while section 7 had so slight a seam as to be hardly an appreciable amount of the area of fracture. Sections 4, 5 and 6 failed with loads per inch of 4,225, 4,020 and 4,270 lbs., respectively, while sections 1 and 7 failed with loads per inch of 3,940 and 4,075 lbs., respectively.

This same condition is found in a comparison of results of tests of sections 2 and 10 of rail No. 10183 with the results of section 8 of the same rail. Section 8 was planed to a thickness of 0.362 of an inch and showed a strength per inch of 4,525 lbs., while speciments 2 and 10, with thicknesses of 0.388 and 0.389 of an inch, respectively, and seams to a depth of 2.8 and 6.4 per cent., respectively, of the entire depth of fracture, showed a strength of only 3,425 and 4,510 lbs., respectively.

CONCLUSIONS.

From the examination of the etched sections of rails failing with square and angular breaks and having in combination a half-moon shaped fracture of the base, it is seen that these rails show deep laminations in the base. The fractures of the base, developed both under the testing machine and in service, occur in lines coinciding with the lines of lamina-

tion and the surfaces of fracture usually present a seam that is a measurable per cent. of the sectional area of the fracture.

That the presence of these seams in rails as rolled has a decided weakening effect on the strength of the base has been shown by results of tests of small sections of the base of rails. Therefore, it may be stated that the base failures which precede the ultimate failure of about ninety per cent. of the square and angular breaks, are developed along the seams in the center of the base.

It has been found that the majority of the failures with the half-moon base characteristics occur at the edge of the tie-plates, which may indicate that there are track conditions existing, due to irregularity in tie-plates or ties, which will produce conditions of eccentric loading similar to that in the testing machine, and which is favorable to the development of the fissures in the base due to the seams.

It is the writer's opinion that the laminations in the base of the rails are due to the flowing of the metal when it is being reduced in passing through the rolls; the temperature being too low for the given pressure to form a solid molecular bond at the laminations. This being the case, the reduction in laminations will be very much greater in a process of rolling which would not allow the forcing of the metal together on the base of the flange. An investigation showing the methods of rolling and etched sections from the different steel mills should enable one to determine how this trouble may be reduced.

Appendix G.

RAIL FAILURE STATISTICS FOR YEAR ENDING OCTOBER 31, 1911

By R. Trimble, Chief Engineer
Maintenance of Way, N. W. System, Pennsylvania Lines.

To the Members of the American Railway Engineering Association:

The following report is submitted on the Rail Failure Statistics for the year ending October 31, 1911.

The responses to the American Railway Association circular have been more complete than before. Replies were received from 129 companies, 40 of which either have no information to furnish, or the reports were too incomplete to be of use; 84 companies furnished statistics relating to 12,893,007 tons of rail, 10,088,706 tons of which were Bessemer, 2,600,008 tons Open-Hearth, and 204,293 tons Specials. The time for summarizing the reports was held open until May 14th. The replies of four companies, the Alabama Great Southern, the Ann Arbor, the San Pedro, Los Angeles & Salt Lake and the Delaware & Hudson Railroads were received too late to be included in the report.

The tabulation consists of the following:

(1) Information received from each company for Bessemer rail, tables 1 to 46.

(2) Information received from each company for Open-Hearth rail, tables 46 to 67.

(3) Information received from each company for Special rail, tables 68 to 76 (see pp. 373 to 381, this report).

(4) Summary by sections, weights, and kinds of steel, tables 77 to 87.

(5) Data for Diagram No. 1, tables 88 to 90.

(6) Data for Diagram No. 2, tables 91 to 92.

(7) Data for Diagram No. 3, tables 93 to 99.

(8) Data for Diagram No. 4, tables 100 to 103.

(9) Data for Diagram No. 5, table 104.

(10) Report of failures from each company, classified according to position in the ingot, tables 105 to 172.

(11) Report on comparative wear of rails from each company, tables 173 to 190.

Report No. 28, July, 1912.

Note.—It has been decided not to publish all of the detailed statistics submitted. These can be referred to in the Secretary's office by anyone interested.

(12) Diagram No. 1—Comparison between different *weights of rail, Bessemer steel.*

(13) Diagram No. 2—Comparison between different *weights of rail, Open-Hearth steel.*

(14) Diagram No. 3—Comparison between different *sections of rail, Bessemer steel.*

(15) Diagram No. 4—Comparison between different *sections of rail, Open-Hearth steel.*

(16) Diagram No. 5—Comparison between different *manufacturers, Bessemer and Open-Hearth steel.*

(17) Diagram No. 6—Comparison between various *weights of rail, Bessemer steel,* showing graphically results from three years' reports.

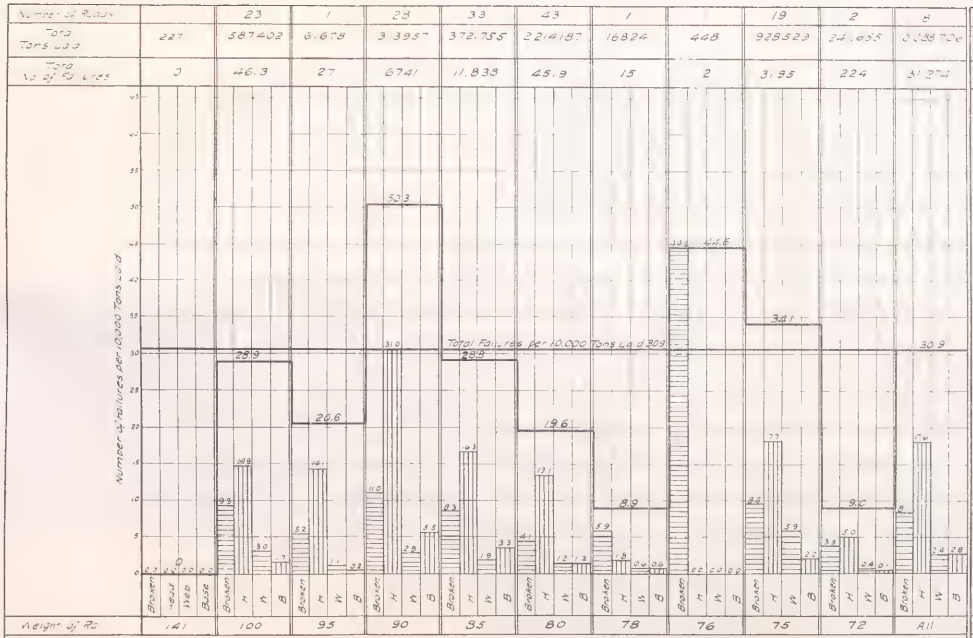
(18) Diagram No. 7—Comparison between various *weights of rail, Open-Hearth steel,* showing graphically results from three years' reports.

The data, tables 68 to 87, are published herewith on pp. 373-392; also such reports on comparative wear on rails as were found to be of value on pp. 393-400. The information on tables 105 to 172, inclusive, is summarized in tables Nos. 7, 7-A and 7-B.

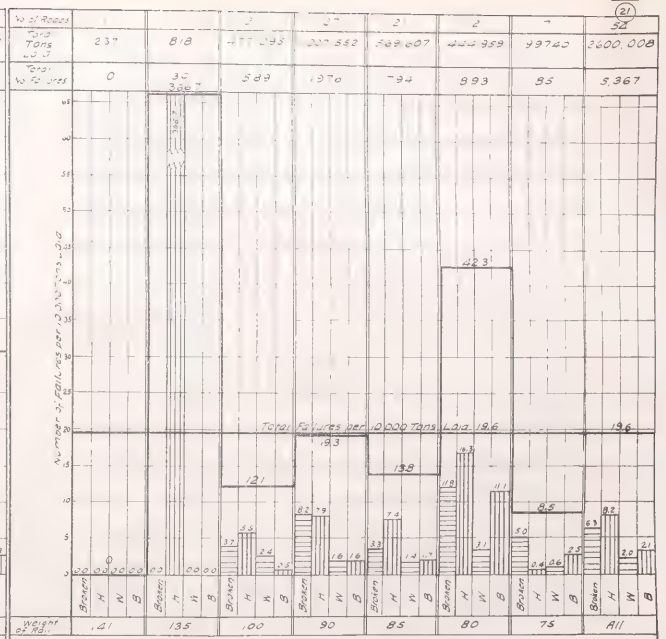
Drawings of the rail sections referred to will be found in Vol. 12, Proceedings, American Railway Engineering Association, Part 2, page 143, et seq.

Table No. 1—List of Various Lots of Rail for Which No Failures Were Reported.

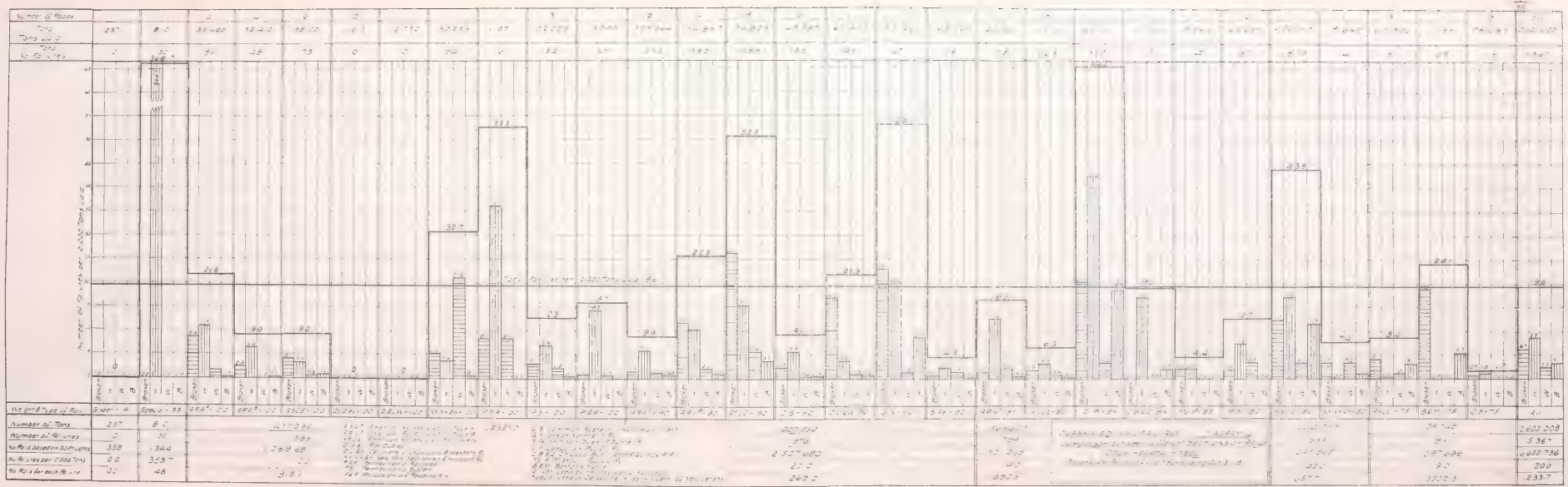
In this list will be found wide variations in chemistry, different kinds of rail, various sections, and rail of widely different time of service. It is to be noted that much of the rail listed has been in service a short time.

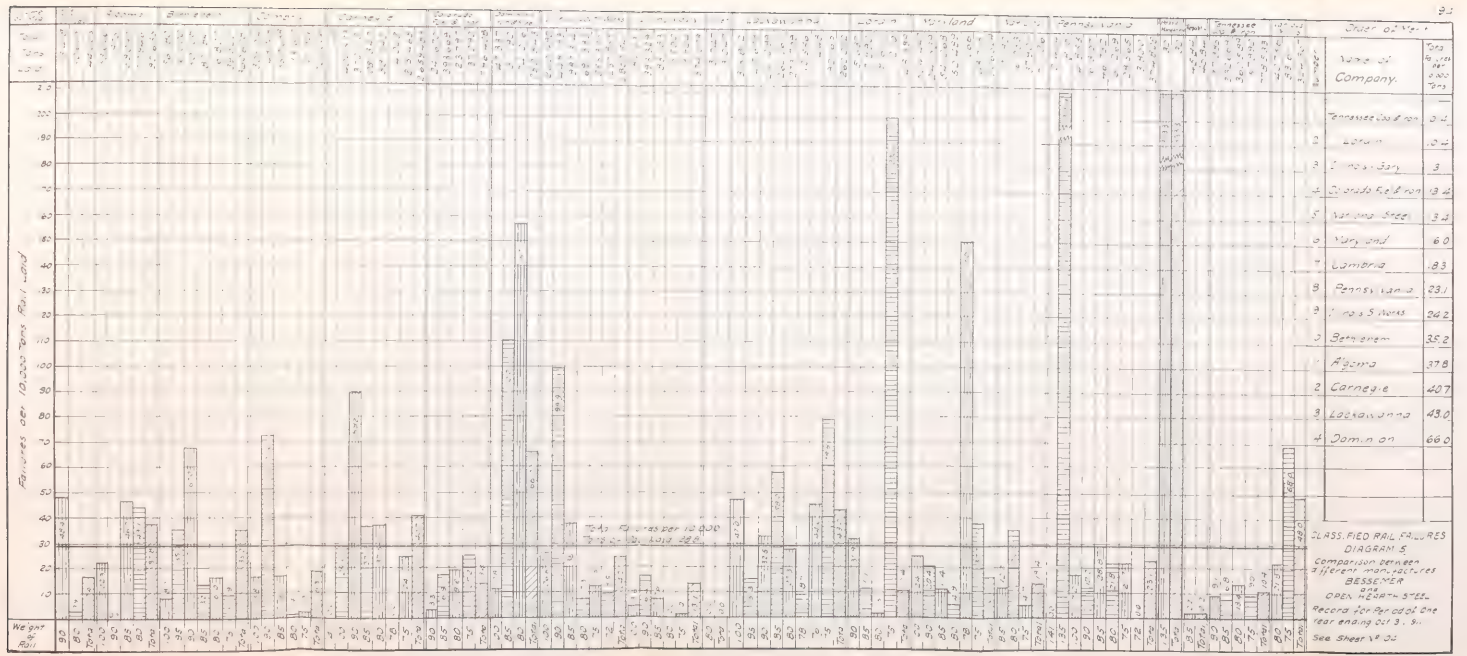


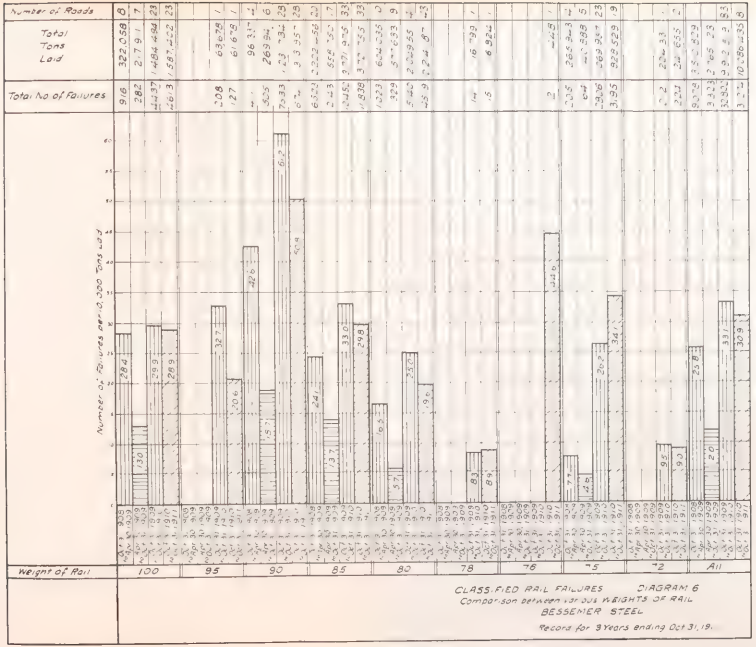
CLASSIFIED RAIL FAILURES DIAGRAM 1
Comparison between different WEIGHTS OF RAIL
BESSEMER STEEL
Record for Period of One Year ending Oct 31, 1911
See Sheets Nos 88, 89 and 90 for names of Railroads and Tons Laid.



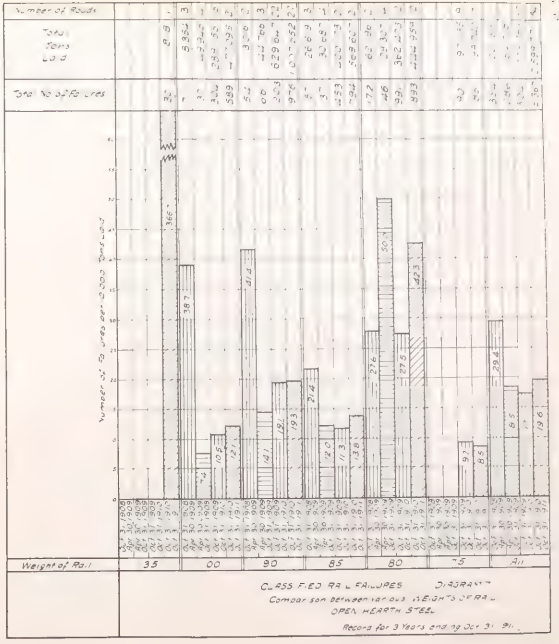
CLASSIFIED RAIL FAILURES DIAGRAM 2
Comparison between different WEIGHTS OF RAIL
OPEN HEARTH STEEL
Record for Period of One Year ending Oct. 31, 1911.
See Sheets Nos 91 and 92 for names of Railroads and Tons Laid.


Number of Tons per 2,000 Tons Unit
Weight Type of Rail
Number of Tons
Number of Rail Lines
No Rail Sections Shipping
No Rail Lines per 2000 Tons
No Rail Joints for each Rail Line
Spec. 1 - A
Spec. 1 - B
Spec. 3 - 39
237
8.0
32.400
12.420
48.60
0
0.720
10.554
1.07
12.097
9.000
2
17.994
0.180
0.360
0.180
0.180
0.180


Failures per 10,000 Tons Rail Laid
Weight of Rail
Tons Failures per 10,000 Tons Rail Laid
Table of Values
Name of Company.
Tons Failures per 10,000 Tons
1 Tennessee Coal Iron 3.4
2 Lorain 10.4
3 Illinois Steel 3
4 Colorado Fuel Iron 13.4
5 Worcester Steel 3.4
6 Maryland 6.0
7 California 18.3
8 Pennsylvania 23.1
9 Illinois Steel 26.2
10 Bethlehem 35.2
11 Algoma 37.8
12 Carnegie 40.7
13 Lackawanna 43.0
14 Dominion 66.0
CLASSIFIED RAIL FAILURES
DIAGRAM 5
Comparison between 5 different manufactures
BESSEMER
OPEN HEARTH STEEL
Record for Period of One Year ending Oct 31 '04
See Sheet No 94



CLASSIFIED RAIL FAILURES DIAGRAM 6
Comparison between various WEIGHTS OF RAIL
BESSEMER STEEL
Record for 3 Years ending Oct 31, 19..



CLASSIFIED RAIL FAILURES DIAGRAM 7
Comparison between various WEIGHTS OF RAIL
OPEN HEARTH STEEL
Record for 3 Years ending Oct 31, 19..

CLASSIFIED RAIL FAILURES.

Diagram 1.

Comparison Between Different Weights of Rail—Bessemer Steel.

Diagram 2.

Comparison Between Different Weights of Rail—Open-Hearth Steel.

Diagram 3.

Comparison Between Different Sections of Rail—Bessemer Steel.

Diagram 4.

Comparison Between Different Sections of Rail—Open-Hearth Steel.

Diagram 5.

Comparison Between Different Manufactures—Bessemer and Open-Hearth Steel.

Diagram 6.

Comparison Between Various Weights of Rail—Bessemer Steel.

Diagram 7.

Comparison Between Various Weights of Rail—Open-Hearth Steel.

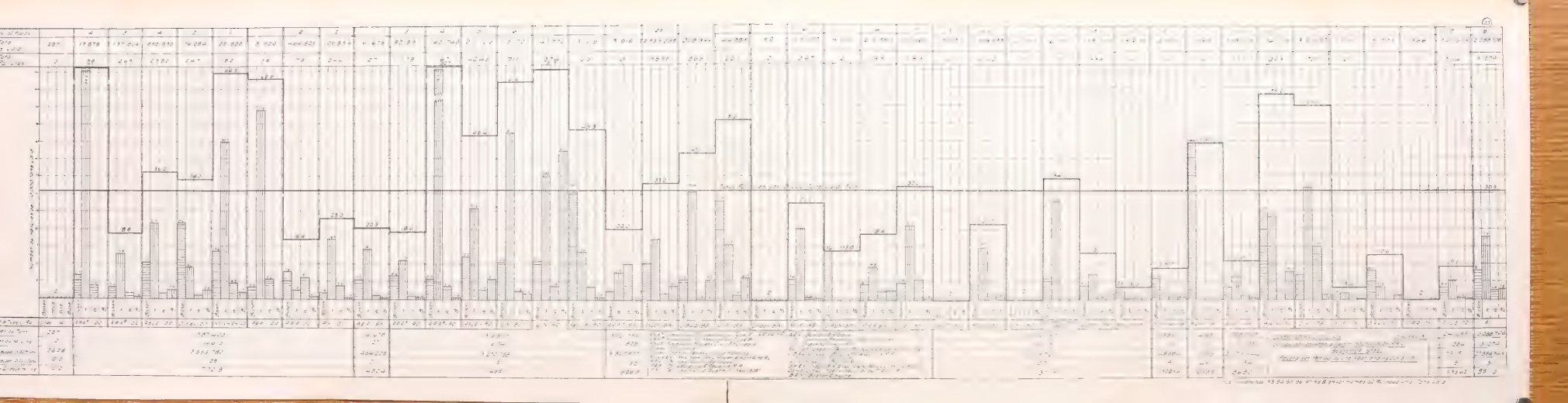


TABLE No. 1—TABULATED STATEMENT OF RAILS HAVING NO FAILURES.

Weight per Yard	Section	Kind of Steel	Manufacturer	Year	Specified Chemical Composition						Railroad
					C.	P.	Mn.	Si.	S.		
100	A. R. A. "B"...	Bessemer.....	Maryland.....	1910	.50	.06	.98	.06	.06	.....	Chesapeake & Ohio
100	A. S. C. E.....	Bessemer.....	Carnegie.....	1896–1902	.50	.08	1.00	.13	.....	.....	Penna. Lines East
			Cambria.....								
100	A. S. C. E.....	Bessemer.....	Cambria.....	1904	.40	.07	1.20	.....	.....	.....	Penna. Lines—N. W. System
100	N.Y.N.H.&H...	Bessemer.....	Carnegie.....	1904	.45	.10	.80	.20	.....	.....	New York, New Haven & Hartford
					.55		1.10				
100	P. R. R.....	Bessemer.....	Lackawanna.....	1893–1907	.50	.08	1.00	.13	.....	.....	Penna. Lines East
90	A. R. A. "A"...	Bessemer.....	Col. Fuel & Iron.....	1911	.63	.04	.70	.20	.....	.....	Union Pacific
					.76		1.00				
90	A. R. A. "B"....	Bessemer.....	Illinois.....	1911	.45	.095	.87	.112	.....	.....	Copper Range R. R.
85	A. S. C. E.....	Bessemer.....	Maryland.....	1907	.48	.10	.80	.20	.....	.....	Chicago & Eastern Illinois
					.58		1.10				
85	A. S. C. E.....	Bessemer.....	Carnegie.....	1901–1906	.43	.10	.80	.20	.....	.....	Illinois Central
					.53		1.10				
85	A. S. C. E.....	Bessemer.....	Maryland.....	1901–1903	.40	.07	1.00	.....	.....	.....	Long Island
					.66		1.20				
85	A. S. C. E.....	Bessemer.....	Carnegie.....	1901–1907	.50	.08	1.00	.13	.....	.....	Penna. Lines East
			Cambria, Maryland....								
85	A. S. C. E.....	Bessemer.....	National.....	1900	.....	.....	.....	.....	.....	.....	Penna. Lines—S. W. System
85	A. S. C. E.....	Bessemer.....	Carnegie.....	1905	.44	.009	.85	.06	.....	.....	Rock Island Lines
					.52	.095	.95	.075			
85	A. S. C. E.....	Bessemer.....	Illinois.....	1911	.43	.10	.80	.20	.....	.....	Southern
					.53		1.10				
85	A. S. C. E.....	Bessemer.....	Illinois.....	1903–1906	.48	.10	.80	.20	.....	.....	Toledo, Peoria & Western
					.58		1.10				
85	P. R. R.....	Bessemer.....	Cambria.....	1906–1909	.51	.095	.89	.053	.056	.....	Baltimore, Chesapeake & Atlantic
					.56	.099	1.00	.078	.086		
85	P. R. R.....	Bessemer.....	Maryland.....	1910	.48	.056	1.00	.054	.056	.....	Baltimore, Chesapeake & Atlantic
85	P. R. R.....	Bessemer.....	Cambria.....	1897	.30	.....	1.00	.12	.....	.....	Penna. Lines—S. W. System
					.50						
80	A. R. A. "A"....	Bessemer.....	Illinois.....	1909–1911	.40	.10	.75	.20	.....	.....	Toledo, Peoria & Western
					.50		1.05				
80	A. R. A. "A"....	Bessemer.....	Illinois.....	1910–1911	.....	.....	.....	.....	.....	.....	Toledo, St. Louis & Western
80	A. S. C. E.....	Bessemer.....	Maryland.....	1904–1908	.50	.085	.80	.20	.075	.....	Houston & Texas Central
					.60		1.10				
80	A. S. C. E.....	Bessemer.....	Cambria.....	1895–1907	.40	.07	1.00	.....	.....	.....	Long Island
					.60		1.20				

TABLE No. 1—TABULATED STATEMENT OF RAILS HAVING NO FAILURES—CONTINUED.

Weight per Yard	Section	Kind of Steel	Manufacturer	Year	Specified Chemical Composition						Railroad
					C.	P.	Mn.	Si.	S.		
80	A. S. C. E.	Bessemer	Algoma	1902	.446	.097	.901	.107	.052		Michigan Central
80	A. S. C. E.	Bessemer	Lackawanna	1906–1911	.48	.10	1.00	.18			Munising
80	A. S. C. E.	Bessemer	Illinois	1896–1906	.48	.09	.92	.094			Munising
80	A. S. C. E.	Bessemer	Cambria	1889–1901	.50	.08	1.00	.13			Penna. Lines East
80	A. S. C. E.	Bessemer	Carnegie	1905	.44	.009	.85	.060			Rock Island Lines
					.52	.095	.95	.075			
80	A. S. . E.	Bessemer	National	1901–1902	.43	.10	.80	.20			Rock Island Lines
					.53		1.10				
80	A. S. C. E.	Bessemer	Illinois	1902							Southern Pacific—East of Sparks
80	A. S. C. E.	Bessemer	Illinois	1902–1907	.45	.10	.75	.20			Toledo, Peoria & Western
					.55		1.05				
80	A. S. C. E.	Bessemer	Illinois	1911	.48	.10	1.00	.17			Cincinnati Northern
80	C. S.	Bessemer	Illinois	1902	.55	.085	.90	.20	.075		Texas & New Orleans
78	N.Y.N.H.&H.	Bessemer	Carnegie	1904–1910	.40	.10	.75	.20			New York, New Haven & Hartford
					.50		1.05				
75	A. S. C. E.	Bessemer	Carnegie	1894–1907	.40	.10	.75	.20			Illinois Central
					.50		1.05				
75	A. S. C. E.	Bessemer	Cambria	1905	.48	.10	.80	.20			Southern
					.55		1.10				
75	A. S. C. E.	Bessemer	Lackawanna	1906–1907	.45	.10	.75	.20			Wisconsin & Northern
					.55		1.05				
75	B. & M.	Bessemer	Pennsylvania, Maryland	1891–1893							Boston & Maine
75	C. S.	Bessemer	Maryland	1906	.50	.085	.80	.20	.075		Houston & Texas Central
					.60		1.10				
75	C. S.	Bessemer	Col. Fuel & Iron	1900–1901							So. Pacific—East of Sparks
75	P. R. R.	Bessemer	Cambria, Carnegie, Lackawanna, Pennsylvania	1875–1898	.50	.08	1.00	.13			Penna. Lines East
70	A. S. C. E.	Bessemer	Pennsylvania	1906–1908							New York, Auburn & Lansing
100	A. R. A. "A"	O. H.	Maryland	1910	.62	.04	.60	.20			Central R. R. of New Jersey
					.75		.90				
100	A. R. A. "A"	O. H.	Carnegie	1911	.70	.04	.75	.05			Baltimore & Ohio
					.80		1.00	.20			
100	A. R. A. "A"	O. H.	Bethlehem	1911	.70	.04	.60	.20			Lehigh & Hudson River
					.85		.90				
100	A. R. A. "B"	O. H.	Maryland	1911	.62	.04	.60	.20			Chesapeake & Ohio
					.75		.90				

100	A. S. C. E.	O. H.	Bethlehem	1909–1910	.745	.026	.755	.0855			Lehigh & Hudson
100	A. S. C. E.	O. H.	Illinois	1911	.68	.027	.83	.16	.038		Michigan Central
100	A. S. C. E.	O. H.	Pennsylvania	1911	.70	.04	.80	.20	.06		Boston & Maine
					.80						
100	A. S. C. E.	O. H.	Pennsylvania	1909	.70	.03	.80	.05			Long Island
					.83			.20			
100	Dudley	O. H.	Lackawanna	1908	.62	.03	.80	.10	.04		New York Central & Hudson River
					.72		1.00	.20			
100	Dudley	O. H.	Bethlehem	1909							New York Central & Hudson River
100	Dudley	O. H.	Lackawanna	1911	.62	.04	.70	.10			Boston & Albany
					.75		1.00	.20			
100	D. L. & W.	O. H.	Lackawanna	1911	.70	.04	.80	.10			Delaware, Lackawanna & Western
					.83		1.10	.20			
100	D. L. & W.	O. H.	Bethlehem	1911	.70	.04	.80	.10			Delaware, Lackawanna & Western
					.83		1.10	.20			
100	D. L. & W.	O. H.	Pennsylvania	1911	.70	.04	.80	.10			Delaware, Lackawanna & Western
					.83		1.10	.20			
100	A. S. C. E.	O. H.	Illinois	1911	.62	.04	.70	.10			Lake Shore & Michigan Southern
					.75		1.00	.20			
100	A. S. C. E.	O. H.	Bethlehem	1911	.62	.04	.70	.10			Lake Shore & Michigan Southern
					.75		1.00	.20			
100	P. S.	O. H.	Illinois	1909	.70	.03	.80	.05			Penna. Lines—N. W. System
					.83			.20			
100	P. S.	O. H.	Carnegie	1909	.70	.03	.80	.05			Penna. Lines—S. W. System
					.83			.20			
100	P. S.	O. H.	Carnegie	1909–1910	.62	.04	.80	.05			Penna. Lines—S. W. System
					.75			.20			
90	A. R. A. "A"	O. H.	Bethlehem	1911	.65	.04	.75	.05			Baltimore & Ohio
					.80		1.00	.20			
90	A. R. A. "A"	O. H.	Bethlehem	1910	.59	.04	.60	.20			Chicago, Burlington & Quincy
					.72		.90				
90	A. R. A. "A"	O. H.	Col. Fuel & Iron	1910–1911	.63	.04	.70	.20			Southern Pacific (East of Sparks)
					.76		1.00				
90	A. R. A. "A"	O. H.	Tenn. Coal & Iron	1910–1911	.63	.04	.70	.20			Texas & New Orleans
					.76		1.00				
90	A. R. A. "A"	O. H.	Tenn. Coal & Iron	1910–1911	.63	.04	.70	.20			Louisiana Western
					.76		1.00				
90	A. R. A. "B"	O. H.	Illinois	1911	.59	.04	.60	.20			Chesapeake & Ohio
					.72		.90				
90	A. R. A. "B"	O. H.	Bethlehem	1910–1911	.62	.04	.80	.05			Northern Pacific
					.75			.20			
90	A. S. C. E.	O. H.	Carnegie	1911	.70	.03	.60	.20			Philadelphia & Reading
					.85		.90				
90	A. S. C. E.	O. H.	Maryland	1911	.62	.04	.60	.20			Philadelphia & Reading
					.75		.90				
90	A. S. C. E.	O. H.	Illinois	1911	.66	.04	.85	.15			Toledo & Ohio Central

TABLE No. 1—TABULATED STATEMENT OF RAILS HAVING NO FAILURES—CONTINUED.

Weight per Yard	Section	Kind of Steel	Manufacturer	Year	Specified Chemical Composition						Railroad
					C.	P.	Mn.	Si.	S.		
90	C. S.	O. H.	Col. Fuel & Iron	1909–1910							Oregon R. R. & Nav. Co.
90	G. N.	O. H.	Algoma	1909							Great Northern
85	A. S. C. E.	O. H.	Bethlehem	1911	.67 .80	.04	.60 .90	.20			Maine Central
85	A. S. C. E.	O. H.	Tenn. Coal & Iron	1911	.55 .65	.04	.60 .90	.20			Nashville, Chatta. & St. Louis
85	A. S. C. E.	O. H.	Tenn. Coal & Iron	1904							Penna. Lines—S. W. System
85	P. S.	O. H.	Cambria	1910	.62 .75	.04	.80	.05 .20			Grand Rapids & Indiana
85	P. S.	O. H.	Carnegie	1908–1911	.69	.028 .030	.70 .71	.118 .143	.027 .035		Penna. Lines East
85	P. S.	O. H.	Carnegie	1909	.70 .83	.03	.80	.05 .20			Penna. Lines—N. W. System
85	P. S.	O. H.	Carnegie	1909	.62 .75	.04	.80	.05 .20			Penna. Lines—N. W. System
85	P. S.	O. H.	Carnegie	1909	.70 .83	.03	.80	.05 .20			Penna. Lines—S. W. System
85	P. S.	O. H.	Carnegie	1909	.62 .75	.04	.80	.05 .20			Penna. Lines—S. W. System
80	A. S. C. E.	O. H.	Bethlehem	1911	.77	.016	.76		.035		Central New England
80	A. S. C. E.	O. H.	Penna	1909	.70 .83	.03	.80 1.10	.20			Long Island
80	A. S. C. E.	O. H.	Illinois	1911	.60 .73	.04	.70 1.00	.10 .20			Peoria & Eastern
80	A. S. C. E.	O. H.	Algoma	1909	.56 .66	.06	.80 1.00	.075 .180	.055		Canadian Pacific
75	A. S. C. E.	O. H.	Illinois	1910	.55 .68	.04	.70 1.00	.20			Illinois Central
75	A. S. C. E.	O. H.	Tenn. Coal & Iron	1910	.55 .68	.04	.70 1.00	.20			Illinois Central
75	B. & M.	O. H.	Bethlehem	1911							Boston & Maine
75	C. S.	O. H.	Col. Fuel & Iron	1908–1911	.45 .63	.085	.75 1.00	.20			Houston & Texas Central
100	A. R. A. "B"	Nickel Chrome.. Bessemer	Maryland	1911	.678	.0101	.677	.063	.0528		Norfolk & Western
100	A. R. A. "A"	Ferro Titanium.. Bessemer	Lackawanna	1910	.50 .60	.10	.84 1.14	.20			Central of New Jersey

100	A. R. A. "A"....	Ferro Titanium..	Lackawanna.....	1911	.50	.10	.90	.....	.....	F. T.	Chicago, Burlington & Quincy
		Bessemer.....			.60		1.10	.....		.30	
100	A. R. A. "B"....	Ferro Titanium..	Maryland.....	1910–1911	.46	.10	.80	.05	Titan	Alloy	Baltimore & Ohio
		Bessemer.....			.56		1.20	.20	.30	.50	
									1.00	1.50	
100	D. L. & W.....	Ferro Titanium..	Lackawanna.....	1911	.616	.092	.61	.108	.....	.....	Delaware, Lackawanna & Western
		Bessemer.....									
100	A. S. C. E.....	Ferro Titanium..	Lackawanna.....	1909	.....	.....	.....	.....	.....	.....	Lake Shore & Michigan Southern
		Bessemer.....									
100	A. R. A. "A"....	Mayari.....	Maryland.....	1911	.50	.10	.84	.20	.....	.....	Central of New Jersey
		Bessemer.....			.60		1.14				
100	A. S. C. E.....	Mayari.....	Maryland.....	1911	.....	.....	.....	.....	.....	.....	Boston & Maine
		Bessemer.....									
90	A. R. A. "B"....	Ferro Titanium..	Lackawanna.....	1910–1911	.44	.10	.90	.13	.....	F.T.	Northern Pacific
		Bessemer.....			.54		1.10	.20	.....	.375	
80	A. S. C. E.....	Ferro Titanium..	Lackawanna.....	1911	.48	.10	1.00	.18	.....	F. T.	Munising, Marquette & Southeastern
		Bessemer.....								.30	
100	A. R. A. "B"....	Ferro Titanium..	Maryland.....	1911	.70	.10	.80	.05	.....	F. T.	Baltimore & Ohio
		Open-Hearth....			.80		1.20	.20		1.0	
90	A. R. A. "B"....	Ferro Titanium..	Maryland.....	1911	.65	.04	.75	.05	.....	F. T.	Baltimore & Ohio
		Open-Hearth....			.80		1.00	.20		1.0	
101	D. L. & W.....	Chrome, Nickel.	Pennsylvania.....	1911	.778	.014	.75	.07	.052	Ni 1.63	Delaware, Lackawanna & Western
		Open-Hearth....								Cr. 0.12	
100	N. Y. N. H. & H.	Mayari.....	Maryland.....	1911	.59	.04	.60	.20	Cr. 0.30	Ni.	New York, New Haven & Hartford
		Open-Hearth....			.72		.90		0.45	.50	
141	Girder.....	Open-Hearth....	Pennsylvania.....	1909–1911	.85	.012	.65	.041	.....	.....	Penna. Lines East
141	Girder.....	Bessemer.....	Pennsylvania.....	1902–1910	.50	.08	1.00	.013	.....	.....	Penna. Lines East
141	Girder.....	Bessemer.....	Carnegie.....	1902–1906	.50	.08	1.00	.013	.....	.....	Penna. Lines East
85	Girder.....	Bessemer.....	Pennsylvania.....	1902–1906	.50	.08	1.00	.13	.....	.....	Penna. Lines East
90	A. R. A. "B"....	Electric.....	Illinois.....	1910–1911	.50	.06	.50	.10	.....	.....	Northern Pacific
					.65		.80	.18			
90	A. R. A. "A"....	Electric.....	Illinois.....	1910	.50	.016	.52	.049	.017	.....	Union Pacific
					.66	.064	.76	.200	.043		
80	A. S. C. E.....	Electric.....	Illinois.....	.....	.....	.....	.....	.....	.....	.....	Lake Shore & Michigan Southern
80	Rerolled.....	Bessemer.....	Joliet.....	1905–1908	.50	.08	1.00	.13	.....	.....	Penna. Lines East

Table No. 2—List of Largest Number of Failures Arranged in Diminishing Order Down to 50, for Convenience in Studying Composition.

Table No. 1 should be considered in connection with Table No. 2. This table shows:

(1) Wide variations in performance of different sections.

(2) Wide variations in performance of different mills.

(3) Same weights and sections do not give uniform results.

(4) Difference in carbon does not account for variation in rate of failure.

(5) Comparison of Open-Hearth and Bessemer shows that Open-Hearth and Bessemer both have high rates of failure as well as low rates in individual cases.

(6) The so-called improved sections, such as A. R. A., give poor results in individual cases, while the older sections, such as the A. S. C. E., give good results in some cases.

(7) It is also to be noted that much of the rail listed in Table No. 2 has been in service a short time.

TABLE No. 2—TABULATED STATEMENT OF LARGEST NUMBER OF FAILURES.

	No. Failures per 10,000 Tons	Wt.	Section	Kind of Steel	Manufactu'r	Year	Specified Chemical Composition						Predominant Failures	Railroad
							C.	P.	Mn.	Si.	S.			
							.50	.....	.70	.10	.20	.50		
A	2155.5	90	A. R. A. "B"	O. H. Chrome Nickel..	Bethlehem.	1909	.60	.04	1.00	.20	.50	.90	Broken—Split Head..	Baltimore & Ohio
				O. H.			.....	.....	.....	.....	.....	.....		
B	1938.0	90	A. S. C. E....	Chrome Nickel..	Bethlehem.	1909	.....	.....	.....	.....	.....	.....	Broken—Split Head..	Central of New Jersey
							.45	.....	.84	.....	.....	F.T.		
C	804.0	90	A. S. C. E....	Bess. Ferro Titan.	Lackawanna	1909	.55	.10	1.14	.20	.....	0.3	Broken Base.....	Central of New Jersey
				O. H.						Ni.		Cr.		
D	743.0	91	D. L. & W....	Chrome Nickel.	Bethlehem.	1909	.535	.033	.654	.200	.435	.541	Broken—Split Head..	Delaware, Lackawanna & Western
				Ferro Titan.			.44	.....	.90	.13	.....	F.T.	Flow of Metal Crushed	
1	446.0	90	A. S. C. E....	Bess.....	Lackawanna	1910	.54	.10	1.10	.20	.075	0.3	Head.....	Wheeling & Lake Erie
2	418.7	80	A. S. C. E....	Bess.....	Lackawanna	1904-10	.....	.....	.....	.....	.....	.....	Flow of Metal Crushed Head	Central Vermont
3	400.0	75	A. S. C. E....	Bess.....	Illinois.....	1905	.....	.....	.....	.....	.....	.....	Only 8 Failed.....	Toledo, St. Louis & Western
							.90	.....	.60	.....	.....	.....		
4	367.0	135	Special.....	O. H.....	Pennsylv'nia	1910	1.10	.03	.80	.20	.....	.....	Split Head.....	Central of New Jersey
							.46	.....	.80	.05	.....	.....		
5	361.8	100	A. R. A. "A"	Bess.....	Maryland...	1909-10	.56	.10	1.20	.20	.....	.....	Cr. and Spl. Head...	Baltimore & Ohio
				O. H.			1.00	.06	11.0	.25	.02	.....		
6	333.3	135	Special.....	Manganese.....	Passaic.....	1908	1.20	.11	13.0	.40	.04	.....	Broken—Only 1 Failure	Delaware & Hudson
							.65	.....	.75	.05	.....	.....		
7	284.7	90	A.R.A. "B"..	O. H.....	Bethlehem.	1908-11	.80	.04	1.00	.20	.06	.....	Broken.....	Baltimore & Ohio
					Dominion		.56	.....	.75	.10	.....	.....		
8	271.0	80	A. S. C. E....	O. H.....	Iron & Steel	1906-08	.75	.06	1.05	.20	.06	.....	Broken Base.....	Canadian Pacific
							.50	.....	.80	.....	.....	.....	Broken—Cr. and Spl.	
9	261.8	90	C. S.....	Bess.....	Illinois.....	1906	.60	.10	1.10	.20	.075	.....	Head.....	Oregon Short Line
10	254.1	100	A.R.A. "A"..	Bess.....	Carnegie....	1909	.50	.10	1.00	.12	.....	.....	Split Head.....	Penna. Lines—S. W. System
11	254.1	100	P. S.....	Bess.....	Maryland...	1908	.50	.10	1.00	.12	.....	.....	Split Head.....	Penna. Lines—S. W. System
							.48	.....	.80	.....	.....	.....		
12	253	100	A. S. C. E....	Bess.....	Illinois.....	1907	.58	.10	1.10	.20	.....	.....	Split Head.....	Chicago, Burlington & Quincy
							.48	.....	.80	.....	.....	.....		
13	249.7	85	A. S. C. E....	Bess.....	Carnegie....	1906-08	.58	.10	1.10	.20	.....	.....	Broken.....	Northern Pacific
							.45	.....	.85	.05	.....	.....		
14	246	90	A. R. A. "B"	Bess.....	Carnegie....	1908-11	.55	.10	1.15	.20	.075	.....	Cr. & Spl. Head.....	Baltimore & Ohio
							.50	.....	.80	.....	.....	.....	Crushed Head, Broken	Cleveland, Cincinnati, Chi-
15	220.8	90	A. S. C. E....	Bess.....	Lackawanna	1906	.60	.10	1.10	.20	.....	.....	Base.....	cago & St. Louis

TABLE No. 2—TABULATED STATEMENT OF LARGEST NUMBER OF FAILURES—CONTINUED.

	No. Failures per 10,000 Tons	Wt.	Section	Kind of Steel	Manufactu'r	Year	Specified Chemical Composition						Predominant Failures	Railroad
							C.	P.	Mn.	Si.	S.			
							.43	.....	.80	.....	.....	.....		
16	215.0	75	B. & M.....	Bess.....	Lackawanna	1904–10	.53	.10	1.10	.20	.....	.....	Broken—Crushed Hd.	Boston & Maine
				Ferro Titan.								F.T.	Only 4 Failed. All	
17	212.8	90	A.R.A. "A"..	Bess.....	Lackawanna	1911	.54	.10	1.10	.20	.....	0.3	Broken.....	Atchison, Topeka & Santa Fe
					Colorado		.57	.....	.80	.10	.....	.....	2 Broken, 1 Crushed	
18	208.0	85	A. S. C. E....	O. H.....	Fuel & Iron.	1909–10	.65	.075	1.00	.20	.075	.....	Head.....	Atchison, Topeka & S nta Fe
19	200.0	75	A. S. C. E....	Bess.....	Lorain.....	1905	.....	.....	.....	.....	.....	.....	Only 4 Failed.....	Toledo, St. Louis & Western
				Ferro Titan.			.45	.....	.80	.05	.....	F. T.		
20	200.0	85	A. S. C. E....	Bess.....	Illinois.....	1911	.55	.10	1.20	.20	.....	0.3	Only 2 Failures.....	Vandalia
							.48	.....	.80	.10	.....	.....		
21	199.0	85	A. S. C. E....	Bess.....	Carnegie....	1908	.58	.10	1.10	.20	.075	.....	Crushed Head.....	Carolina, Clinchfield & Ohio
							.50	.....	.80	.....	.....	.....		
22	192.0	80	A. S. C. E....	Bess.....	Carnegie....	1904–05	.60	.085	1.10	.20	.075	.....	Split Head.....	Union Pacific
				Ferro Titan.			.44	.....	.90	.13	.....	F. T.	Broken—Flow of Met-	
23	192.0	90	A. S. C. E....	Bess.....	Lackawanna	1910	.54	.10	1.10	.20	.075	0.3	al, Cr. Hd., Sp. Hd.	Wheeling & Lake Erie
24	191.0	90	A. S. C. E....	O. H.....	Lackawanna	1908	.....	.....	.....	.....	.....	.....	.....	Lehigh Valley
							.47	.....	.82	.....	.....	.....		
25	181.0	90	A. S. C. E....	Bess.....	Carnegie....	1900–10	.57	.10	1.10	.20	.075	.....	Split Head.....	Pittsburgh & Lake Erie
							.45	.....	.80	.....	.....	.....		
26	175.0	90	A. S. C. E....	Bess.....	Carnegie....	1905–10	.55	.10	1.10	.20	.....	.....	Cr. & Split Head.....	Wheeling & Lake Erie
27	156.6	85	P. S.....	Bess.....	Carnegie....	1909–11	.50	.10	1.00	.12	.....	.....	Cr. & Split Head.....	Penna. Lines—N. W. System
					Dominion		.55	.....	.80	.15	.....	.....		
28	156.1	80	A. S. C. E....	O. H.....	Iron & Steel	1906–09	.65	.065	1.10	.20	.069	.....	Broken.....	Grand Trunk
							.46	.....	.80	.05	.....	.....		
29	147.6	100	A.R.A. "A"..	Bess.....	Carnegie....	1909	.56	.10	1.20	.20	.....	.....	Cr. & Spl. Head.....	Baltimore & Ohio
					Maryland		1.10	.....	11.50	.....	.....	.....		
30	142.8	85	A. S. C. E....	Manganese.....	Steel Co....	1909–10	1.20	.06	12.00	.....	.04	.....	Broken and Split Web	Atchison, Topeka & Santa Fe
							.54	.....	.90	.....	.....	.....		
31	141	90	A. S. C. E....	Bess.....	Cambria...	1907	.64	.10	1.15	.20	.....	.....	Split Head.....	Central of New Jersey
							.43	.....	.80	.....	.....	.....		
32	131.3	85	A. S. C. E....	Bess.....	Lackawanna	1906–09	.58	.10	1.10	.20	.....	.....	Broken—Broken Base.	Northern Pacific
33	128.2	90	A. S. C. E....	O. H.....	Bethlehem.	1908–09	.57	.031	.82	.....	.....	.....	Broken.....	Central of New Jersey
34	125.0	85	Mo. Pac.....	Bess.....	Carnegie....	1897–09	.48	.10	.95	.20	.....	.....	Cr. & Spl. Head.....	Denver & Rio Grande
							.53	.....	.....	.....	.....	.....		
35	124.1	85	C. B. & Q....	Bess.....	Carnegie....	1906–07	.48	.10	.80	.....	.....	.....	Split Head.....	Chicago, Burlington & Quincy
							.58	.....	1.10	.20	.....	.....		
36	123.4	90	A. S. C. E....	O. H.....	Bethlehem.	1907–10	.62	.04	.80	.....	.....	.....	Broken.....	Lehigh Valley
							.75	.....	1.05	.....	.....	.....		

							.50			.80				
37	122.9	80	A. S. C. E....	Bess.....	Lackawanna	1904	.60	.085	1.10	.20	.075	.....	Split Head.....	Union Pacific
							.43	.....	.80	.....	.....	.....		
38	121.4	85	A. S. C. E....	Bess.....	Illinois....	1903-09	.58	.10	1.10	20	.....	.....	Broken—Broken Base.	Northern Pacific
39	120.0	85	P. S.....	Bess.....	Cambria...	1908	.50	.10	1.00	.12	.....	.....	Split Head.....	Penna. Lines—N. W System
40	119.7	90	G. N.....	Bess.....	Lackawanna	1908-10	.49	.10	.95	.20	.....	.....	Broken Base.....	Great Northern
				Ferro Titan.			.62	.....	.70	.....	.....	.....	Crushed Head, Split	
41	119.5	90	G. N.....	Bess.....	Lackawanna	1909	.75	.04	1.10	.20	.....	.....	Head.....	Great Northern
							.45	.....	.80	.....	.....	.....	Broken—Split Head	
42	118.8	90	A. S. C. E....	Bess.....	Cambria...	1903-09	.55	.10	1.20	.20	.....	.....	and Web.....	Lehigh Valley
					Lackawanna		.40	.....	.80	.13	.....	.....		
43	118.6	85	A. S. C. E....	Bess.....	Pennsylvania	1905-10	.58	.10	1.10	.20	.075	.....	Broken.....	Maine Central
							.45	.....	.80	.05	.....	.....		
44	114.0	90	A.R.A. "B"..	Bess.....	Cambria...	1909-11	.55	.10	1.20	.20	.....	.....	Cr. & Spl. Head.....	Baltimore & Ohio
							.48	.....	.80	.....	.....	.....		
45	112.6	80	A. S. C. E....	Bess.....	Lackawanna	1904-09	.58	.10	1.10	.20	.....	.....	Broken.....	Grand Trunk
				Ferro Titan.			.43	.....	.90	.13	.....	F. T.	Broken—Cr. & Split	
46	110.0	80	Dudley.....	Bess.....	Lackawanna	1910	.53	.10	1.10	.20	.075	0.33	Head Br. Base.....	N. Y. C. & Hudson River
					Dominion		.55	.015	.70	.075	.....	.....		
47	110.0	85	C. P. R.....	O. H.....	Iron & Steel	1908-10	.70	.06	1.00	.18	.055	.....	Split Head.....	Canadian Pacific
							.48	.....	.84	.....	.....	.....		Pittsburgh & Lake Erie (P. &
48	109.0	100	A.R.A. "B"..	Bess.....	Carnegie....	1908-11	.58	.10	1.14	.20	.....	.....	Broken.....	L. E. Div.)
49	106.6	85	P. S.....	Bess.....	Cambria...	1908-09	.50	.10	1.00	.12	.....	.....	Cr. & Spl. Head.....	Penna. Lines—S. W. System
				Ferro Titan.			.70	.....	.80	.....	.....	F. T.	Broken—Split Head &	
50	105.7	90	A. S. C. E....	O. H.....	Bethlehem.	1910	.80	.04	1.05	.....	.....	0.05	Web, Broken Base..	Lehigh Valley
51	103.8	100	N.Y.N.H.&H	Bess.....	Lackawanna	1892-11	.....	.....	.....	.....	.....	.....	Crushed Head.....	New York, New Haven & Hartford
							.43	.....	.75	.....	.....	.....		
52	103.0	80	A. S. C. E....	Bess.....	Lackawanna	1906-11	.55	.10	1.10	.20	.075	.....	Broken.....	Erie
53	100.2	100	P. S.....	Bess.....	Cambria...	1908-10	.50	.10	1.00	.12	.....	.....	Flow of Metal.....	Penna. Lines—S. W. System
54	100.0	100	P. S.....	Bess.....	Maryland...	1908	.50	.10	1.00	.12	.....	.....	Crushed Head.....	Penna. Lines—N. W. System
							.50	.....	.80	.....	.....	.....		Cleveland, Cincinnati, Chi-
55	100.0	90	A. S. C. E....	Bess.....	Carnegie....	1905-10	.60	.10	1.10	.20	.....	.....	Cr. & Split Head.....	cago & St. Louis
							.40	.....	.....	.....	.....	.....		
56	98.9	100	A. S. C. E....	Bess.....	Carnegie....	1901-07	.50	.07	1.20	.....	.....	.....	Cr. & Spl. Head.....	Penna. Lines—N. W. System
							.44	.....	.82	.....	.....	.....		
57	98.7	80	A. S. C. E....	Bess.....	Carnegie....	1901-10	.54	.10	1.10	.20	.075	.....	Split Head.....	Pittsburgh & Lake Erie
							.45	.....	.75	.....	.....	.....		
58	98.4	75	C. S.....	Bess.....	Carnegie....	1905-11	.55	.10	1.00	.20	.075	.....	Cr. & Split Head.....	Oregon R. R. & Nav. Co.
							.45	.....	.80	.05	.....	.....		
59	98.5	90	A.R.A. "A"..	Bess.....	Carnegie....	1909-11	.55	.10	1.20	.20	.....	.....	Split Head.....	Baltimore & Ohio
							.50	.....	.80	.....	.....	.....		
60	98.3	90	C. S.....	Bess.....	Carnegie....	1906-11	.60	.10	1.10	.20	.075	.....	Split Head.....	Union Pacific
61	96.0	100	A. S. C. E....	Bess.....	Lackawanna	1905-10	.547	.10	.95	.20	.....	.....	Cr. & Split Head.....	Lake Shore & Michigan South-
														ern

TABLE No. 2—TABULATED STATEMENT OF LARGEST NUMBER OF FAILURES—CONTINUED.

	No. Failures per 10,000 Tons	Wt.	Section	Kind of Steel	Manufactu'r	Year	Specified Chemical Composition						Predominant Failures	Railroad
							C.	P.	Mn.	Si.	S.			
							.43		.80					
62	95.4	75	B. & M.	Bess	Penna	1892-98	.53	.10	1.10	.20			Broken	Boston & Maine
63	93.0	85	A. S. C. E.	Bess	Illinois	1[illegible]	.47	.098	.85	.099			Broken	Baltimore & Ohio
							.45		.80					
64	93.0	90	A. S. C. E.	Bess	Carnegie	1906-11	.58	.10	1.15	.20	.075		Flow of Metal, Broken	Erie
					Tennessee		.63		.70					
65	91.5	90	A.R.A. "A"	O. H.	Coal & Iron	1910	.76	.04	1.00	.20			Split Head	Illinois Central
							.43		.80					
66	87.4	85	A. S. C. E.	Bess	Carnegie	1905-09	.53	.10	1.10	.20			Split Head	Chicago & Eastern Illinois
67	87.3	100	P. S	Bess	Cambria	1908-11	.50	.10	1.00	.12			Crushed Head	Penna. Lines—N. W. System
68	85.1	80	A. S. C. E.	Bess	Carnegie	1900-03							Cr. & Spl. Head	Central Vermont
							.43		.80					Cleveland, Cincinnati, Chi-
69	83.2	80	A. S. C. E.	Bess	Carnegie	1898-07	.58	.10	1.10	.20			Cr. & Spl. Head	cago & St. Louis
							.43		.80					
70	83.0	90	G. N.	Bess	Cambria	1908	.53	.10	1.10	.20			Cr. & Spl. Head	Great Northern
							.55		.90					
71	80.7	100	P. & R.	Bess	Maryland	1909-10	.65	.07	1.20	.20			Flow of Metal	Philadelphia & Reading
							.45		.80					
72	79.6	90	A. S. C. E.	Bess	Carnegie	1903-09	.55	.10	1.20	.20			Spl. Hd. & Web	Lehigh Valley
							.50		.80				Broken Base, Spl. &	Cleveland, Cincinnati, Chi-
73	76.6	90	A. S. C. E.	Bess	Illinois	1906-10	.60	.10	1.10	.20			Cr. Head	cago & St. Louis
							.43		.80					
74	75.6	90	G. N.	Bess	Illinois	1908	.53	.10	1.10	.20			Broken Base	Great Northern
							.45		.80	.05				
75	74.5	80	A. S. C. E.	Bess	Illinois	1886-11	.55	.10	1.20	.20			Split Head	B. & O. Chicago Terminal
					Penna.		.65		.70					
76	74.3	80	A. S. C. E.	Bess	Maryland	1904-08	.80	.06	1.00	.20			Crushed Head	Lehigh & Hudson River
							.45		.80	.05				
77	74.0	85	A. S. C. E.	Bess	Carnegie	1899-08	.55	.10	1.20	.20			Crushed Head	Vandalia
							.46		.80	.05				
78	73.7	100	A.R.A. "B"	Bess	Cambria	1910-11	.56	.10	1.20	.20			Cr. & Spl. Head	Baltimore & Ohio
							.43		.80					Buffalo, Rochester & Pitts-
79	69.0	80	Dudley	Bess	Lackawanna	1896-04	.53	.10	1.10	.20			Flow of Metal	burgh
80	68.7	75	C. S.	Bess	Various	1895-08							Spl. Head & Web	Southern Pacific
							.45		.75					
81	68.3	75	C. S.	Bess	Carnegie	1907	.55	.085	1.00	.20	.075		Split Head	Oregon Short Line
					Lackawanna		.40	.085	.75					
82	67 7	75	B. & M.	Bess	Maryland	1896-04	.60	1.00	1.30	.20	.069		Broken	Boston & Maine

83	67.2	90	G. N.	O. H.	Bethlehem	1908-10	.67	.04	.79	.20			Split Head	Great Northern
84	66.0	90	C. S.	Bess	Carnegie	1907	.60	.085	.90	.20	.075		Broken & Split Head	Texas & New Orleans
85	66.0	90	G. N.	Bess	Maryland	1908							Crushed Head	Great Northern
							.43		.80					
86	64.0	75	B. & M.	Bess	Maryland	1892-09	.53	.10	1.10	.20			Broken	Boston & Maine
87	63.4	90	G. N.	O. H.	Illinois	1909-11	.68	.04	.82	.20			Broken	Great Northern
							.45		.80	.05				
88	63.0	85	A. S. C. E.	Bess	Cambria	1901-07	.55	.10	1.20	.20			Cr. & Spl. Head	Vandalia
89	62.3	80	A. S. C. E.	Bess	National	1900-02							Spl. Head	Grand Trunk
90	61.8	80	A. S. C. E.	Bess	Carnegie	1901-07	.55	.085	.90	.20	.075		Cr. & Spl. Head	Galveston, Harrisburg & San Antonio
							.45		.84					Buffalo, Rochester & Pittsburgh
91	61.0	90	A. S. C. E.	Bess	Carnegie	1898-11	.53	.10	1.14	.20			Flow Metal, Spl. Head	
92	60.0	90	A. S. C. E.	Bess	Cambria	1906							Crushed Head	Carolina, Clinchfield & Ohio
							.46		.90	.10				
93	59.2	100	A. S. C. E.	Bess Ferro Titan.	Maryland	1902-08	.56	.10	1.20	.20	.075		Cr. & Spl. Head	Baltimore & Ohio
94	59.0	80	A. S. C. E.	Bess	Lackawanna	1909							Broken & Split Head	Toledo, St. Louis & Western
							.53		.40					
95	58.9	90	A. S. C. E.	Bess	Maryland	1906-10	.57	.10	.60				Broken	Delaware & Hudson
							.55		.80					
96	58.5	90	C. S.	Bess	Illinois	1908-10	.65	.085	1.05	.20			Cr. & Spl. Head	Illinois Central
							.65		.75	.05				
97	58.5	90	A.R.A. "B"	O. H.	Cambria	1910-11	.80	.04	1.00	.20			Split Web	Baltimore & Ohio
							.50							
98	57.0	100	A.R.A. "B"	Bess	Carnegie	1908-11	.60						Cr. & Spl. Head	Bessemer & Lake Erie
							.59		.60					
99	57.0	90	A. S. C. E.	O. H.	Bethlehem	1908-11	.75	.04	.90	.20			Broken	Erie
							.43		.80					
100	56.0	85	A. S. C. E.	Bess	Carnegie	1899	.53	.10	1.10	.20			Split Web	Boston & Maine
							.70		.60	.05				
101	55.6	100	A.R.A. "A"	O. H.	Bethlehem	1910-11	.85	.04	.90	.20			Split Head, Broken	Central of New Jersey
							.53		.80	.10				
102	55.4	80	A. S. C. E.	Bess	Algoma	1905-09	.63	.085	1.00	.20	.075		Broken	Canadian Pacific
							.43		.80					Buffalo, Rochester & Pittsburgh
103	55.0	80	Dudley	Bess	Bethlehem	1892-97	.53	.10	1.10	.20			Spl. Hd. & Web	
							.48		.80					
104	55.0	100	A. S. C. E.	Bess	Lackawanna	1907	.58	.10	1.10	.20			Split Head	Grand Trunk
105	55.0	100	A. S. C. E.	Bess	Carnegie	1905-06	.55	.10	.95	.20			Split Head	Lake Shore & Michigan Southern

TABLE No. 2—TABULATED STATEMENT OF LARGEST NUMBER OF FAILURES—CONTINUED.

	No. Failures per 10,000 Tons	Wt.	Section	Kind of Steel	Manufacturer	Year	Specified Chemical Composition						Predominant Failures	Railroad
							C.	P.	Mn.	Si.	S.			
							.48	.....	.80	.....	.....	.....		
106	53.6	85	C. B. & Q....	Bess.....	Illinois.....	1906–08	.58	.10	1.10	.20	.....	.....	Split Head.....	Chicago, Burlington & Quincy
							.46	.....	.80	.05	.....	.....	Flow Metal, Crushed Head.....	
107	53.6	100	A.R.A. "B"..	Bess.....	Maryland...	1909–11	.56	.10	1.20	.20	.....	.....		Baltimore & Ohio
							.45	.082	.80	.....	0.44	.....		
108	53.5	85	A. S. C. E....	Bess.....	Carnegie....	1902–08	.60	.100	1.00	.20	.053	.....	Cr. & Spl. Head.....	Baltimore & Ohio
							.45	.....	.84	.....	.....	.....	Flow Metal, Broken Base.....	Buffalo, Rochester & Pittsburgh
109	53.0	90	A. S. C. E....	Bess.....	Lackawanna	1898–11	.53	.10	1.14	.20	.....	.....		Nashville, Chattanooga & St. Louis
							.43	.....	.80	.....	.....	.....		
110	52.8	80	A. S. C. E....	Bess.....	Penna.....	1899–04	.53	.10	1.10	.20	.....	.....	Split Head.....	
							.53	.....	.80	.....	.....	.....		
111	51.0	85	C. S.....	Bess.....	Algoma....	1908–10	.63	.085	1.00	.18	.075	.....	Broken.....	Canadian Pacific
112	51.0	85	P. S.....	Bess.....	Carnegie....	1909–11	.50	.10	1.00	.12	.....	.....	Cr. & Spl. Head.....	Penna. Lines—N W. System
							.70	.....	.75	.05	.....	.....		
113	51.0	100	A.R.A. "A"..	O. H.....	Bethlehem.	1910–11	.80	.04	1.00	.20	.....	.....	Broken.....	Baltimore & Ohio
114	51.0	100	A.R.A. "A"..	Bess.....	Illinois.....	1910–11	.....	.....	.....	.....	.....	.....	Cr. & Spl. Head.....	Chicago & Alton
							.490	.076	.970	.087	.046	Cu. .088		
115	50.6	100	A. S. C. E....	Bess.....	Lackawanna	1903–10	.562	.092	1.08	.139	.090	.223	Split Head.....	Michigan Central
							.48	.....	.80	.....	.....	.....		
116	50.5	85	A. S. C. E....	Bess.....	Lackawanna	1904	.58	.10	1.10	.20	.....	.....	Split Head.....	Atchison, Topeka & Santa Fe
							.54	.....	1.05	.....	.....	.....		
117	50.0	90	A. S. C. E....	Bess.....	Carnegie....	1906	.64	.10	1.30	.20	.....	.....	Split Head.....	Central of New Jersey

Table No. 3—Tabulation of Kinds of Failures for Different Weights of Rail and between Bessemer and Open-Hearth Steel. The figures for 1909 and 1910 are added for comparison. (Fractions or decimals omitted. Odd weights of rail omitted).

TABLE No. 3—PERCENTAGE OF FAILURES OF TOTAL FAILURES.

Weight of Rail	Broken		Head Failure		Web Failure		Base Failure		Year
	Bess.	O. H.	Bess.	O. H.	Bess.	O. H.	Bess.	O. H.	
135-lb.	.....	.....	.....	100	.....	.....	.....	.....	1911
100-lb.	20	19	58	41	14	28	8	12	1909
100-lb.	34	23	47	56	9	13	10	8	1910
100-lb.	32	31	51	45	11	20	6	4	1911
95-lb.	14	.....	81	.....	3	.....	2	.....	1910
95-lb.	25	.....	68	.....	6	.....	1	.....	1911
90-lb.	17	34	74	51	6	12	3	3	1909
90-lb.	24	38	58	46	9	11	9	5	1910
90-lb.	21	42	62	41	6	9	11	8	1911
85-lb.	16	21	70	64	6	9	8	6	1909
85-lb.	30	21	53	63	5	11	12	5	1910
85-lb.	28	24	53	53	6	11	12	12	1911
80-lb.	16	15	73	60	6	19	5	6	1909
80-lb.	23	34	67	44	6	12	4	10	1910
80-lb.	21	28	67	38	6	8	6	26	1911
75-lb.	28	.....	52	.....	18	.....	2	.....	1909
75-lb.	32	35	49	30	12	14	7	21	1910
75-lb.	25	59	52	5	17	7	6	29	1911

This table shows that head failures predominate with but one exception, 75-lb. Open-hearth rail in 1911, where broken rails predominate. This is due to a lot of 8,148 tons on the B. & M. R. R., which shows a large proportion of broken rails. There is nothing in the specified chemistry to account for these failures. The rail was rolled by the Pennsylvania Steel Company, 1909 and 1910. Wheel loads are moderate. There were 23 broken rails, 17 on tangent and 6 on curves; one broken base on tangent and 5 broken bases on curves, with no head or web failures.

Table No. 4—A tabulation of the different sections in order of superiority as shown by the record of failures. For comparison the order of merit of last year is also given.

Note the changes in order of superiority between 1910 and 1911. N. Y., N. H. & H., 100-lb. rail which was first in 1910 is No. 7 in 1911, and so through the entire list. This shows that the section does not control the quality of material. The A. R. A. sections are considered an improvement from the mill standpoint on older sections and should give good results on account of the short time of service, but an examination of the detail reports shows differences in performance that cannot be accounted for by the difference in sections. The statement following from last year's report seems to be fully borne out by this year's statistics: *"At the present time, the quality of the material is so variable that neither minor differences in section, or in chemical composition, have serious weight."*

TABLE No. 4—ORDER OF SUPERIORITY OF VARIOUS RAIL SECTIONS ACCORDING TO WEIGHT OF RAIL AND MATERIAL BASED ON RELATIVE NUMBER OF RAIL FAILURES PER 10,000 TONS OF NEW RAIL LAID.

Order	100-lb. Rail			
	Bessemer		Open-Hearth	
	1910	1911	1910	1911
1	N. Y. N. H. & H.	P. R. R.	A. R. A. "B"	D. L. & W.
2	A. R. A. "B"	A. R. A. "B"	A. R. A. "A"	Dudley
3	P. S.	P. S.	P. & R.	A. S. C. E.
4	P. R. R.	Dudley	A. S. C. E.	A. R. A. "B"
5	A. R. A. "A"	A. S. C. E.	Dudley	P. S.
6	P. & R.	P. & R.	P. S.	P. & R.
7	A. S. C. E.	N. Y. N. H. & H.	N. Y. N. H. & H.	A. R. A. "A"
8	Dudley	A. R. A. "A"	P. R. R.	N. Y. N. H. & H.
9				P. R. R.
	90-lb. Rail			
1	A. R. A. "A"	A. R. A. "A"	Santa Fe	Santa Fe
2	G. N.	A. S. C. E.	G. N.	A. R. A. "A"
3	D. L. & W.	Rerolled	A. R. A. "A"	C. S.
4	A. S. C. E.	C. S.	A. R. A. "B"	D. L. & W.
5	C. S.	A. R. A. "B"	C. S.	A. R. A. "B"
6	A. R. A. "B"	G. N.	D. L. & W.	A. S. C. E.
7			A. S. C. E.	G. N.
8				
9				
	85-lb. Rail			
1	Mo. Pac.	O. R. & N.	A. S. C. E.	Mo. Pac.
2	P. R. R.	P. R. R.	P. S.	A. S. C. E.
3	P. S.	A. R. A. "A"	A. R. A. "A"	P. S.
4	A. S. C. E.	Mo. Pac.	Mo. Pac.	A. R. A. "A"
5	Q.	P. S.	Q.	C. B. & Q.
6	A. R. A. "A"	A. S. C. E.		C. P. R.
7		C. B. & Q.		
8		C. P.		
9				
	80-lb. Rail			
1	A. R. A. "A"	A. R. A. "A"		N. Y. N. H. & H.
2	Dudley	C. S.		A. S. C. E.
3	A. S. C. E.	Rerolled		
4	Cambria	Dudley		
5		A. S. C. E.		
6		Cambria		
7				
8				
9				
	75 lb. Rail			
1	Mo. Pac.	P. R. R.	C. S.	C. S.
2	P. R. R.	Mo. Pac.	Lackawanna	B. & M.
3	B. & M.	A. S. C. E.	A. S. C. E.	A. S. C. E.
4	A. S. C. E.	O. R. & N.		
5	C. S.	C. S.		
6		B. & M.		
7				
8				
9				

NOTE: P. R. R.=Old Section Pennsylvania R. R. prior to 1908.
P. S.=New section Pennsylvania System since 1908.

Table No. 5 was prepared with a view of discovering as to whether or not the number of head failures was influenced by the section, that is, whether a thin or deep head is the better or whether a high stiff or low flexible section is the better. The comparison for 1910 is added.

The rate of failure is not uniform for any one section.

TABLE No. 5.—STATEMENT OF HEAD FAILURES, PER 10,000 TONS OF RAIL LAID ARRANGED IN DIMINISHING ORDER.

Bessemer Steel. Sheet 1.

Order	Section	Weight	Number of head failures per 10,000 tons of rail laid		Deep or Thin Head	High or Low Design	Order in 1910
			1911	1910			
1	A. R. A. "B"	90-lb.	73.0	84.3	D	L	1
2	A. R. A. "A"	100-lb.	66.5	15.9	T	H	13
3	P. & R.	100-lb.	53.9	20.3	D	L	8
4	C. S.	90-lb.	47.1	42 8	T	H	3
5	N. Y. N. H. & H.	100-lb.	44.9	2.7	D	H	22
6	G. N.	90-lb.	34.8	11.6	T	L	16
7	C. S.	90-lb.	31.8	42.8	T	H	3
8	C. B. & Q.	85-lb.	30.4	39.3	T	L	4
9	Cambria 540.	80-lb.	27.6	27.0	.....	.....	7
10	A. S. C. E.	90-lb.	25.6	31.4	D	L	5
11	B. & M.	75-lb.	23.5	0.3	.....	.....	25
12	A. S. C. E.	100-lb.	21.5	20.2	D	L	9
13	Mo. Pac.	85-lb.	20.1	1.2	D	L	24
14	P. S.	85-lb.	21.0	29.6	D	L	6
15	A. S. C. E.	85-lb.	17.1	18.1	D	L	12
16	P. S.	100-lb.	16.9	13.0	D	L	15
17	C. P.	85-lb.	15.5	.....	.....	.....	.....
18	A. S. C. E.	80-lb.	14.2	18.5	D	L	11
19	B. & A.	100-lb.	14.1	.....	T	L	.....
20	A. R. A. "B"	100-lb.	12.9	9.7	D	L	17
21	A. R. A. "A"	90-lb.	11.0	13.4	T	H	14
22	P. R. R.	85-lb.	9.2	8.6	D	L	18
23	Dudley.	100-lb.	9.0	19.9	T	H	10
24	A. R. A. "A"	85-lb.	7.5	66.2	T	H	2
25	Dudley.	80-lb.	7.0	7.9	T	H	20
26	A. S. C. E.	75-lb.	6.2	8.5	D	L	19
27	A. S. C. E.	72-lb.	5.2	.....	D	L	.....
28	O. R. & N.	75-lb.	3.4	.....	.....	.....	.....
29	P. R. R.	100-lb.	2.9	4.0	D	L	21
30	N. Y. N. H. & H.	78-lb.	1.8	1.7	D	H	23
31	Mo. Pac.	75-lb.	1.7	1.7	D	L	23

TABLE No. 5—STATEMENT OF HEAD FAILURES, PER 10,000 TONS OF RAIL LAID, ARRANGED IN DIMINISHING ORDER.

Open-Hearth Steel. Sheet 2.

Order	Section	Weight	Number of head failures per 10,000 tons of rail laid		Deep or Thin Head	High or Low Design	Order in 1910	Remarks
			1911	1910				
1	Spec. C.R.R.of N.J..	135-lb.	366.7	.....	.....	.....	.....	Small amount.
2	C. P.....	85-lb.	42.3	.....	.....	.....	.....	
3	P. R. R.....	100-lb.	36.1	43.2	D	L	1	
4	G. N.....	90-lb.	20.1	7.3	T	H	9	
5	A. S. C. E.....	80-lb.	17.0	12.2	D	L	5	
6	C. B. & Q.....	85-lb.	17.0	23.0	T	L	2	
7	A. S. C. E.....	90-lb.	15.1	20.1	D	L	4	
8	P. & R.....	100-lb.	14.2	3.7	D	L	15	
9	A. R. A. "A".....	85-lb.	12.6	7.1	T	H	10	
10	A. R. A. "A".....	100-lb.	10.9	0.5	T	H	20	
11	A. R. A. "B".....	90-lb.	10.1	10.9	D	L	6	
12	P. S.....	85-lb.	7.3	.....	D	L	.....	
13	P. S.....	100-lb.	6.9	8.2	D	L	7	
14	A. R. A. "B".....	100-lb.	6.4	10.9	D	L	6	
15	C. S.....	90-lb.	5.9	5.5	T	H	14	
16	A. R. A. "A".....	90-lb.	5.7	8.1	T	H	8	
17	N. Y. N. H. & H....	100-lb.	3.6	2.0	D	H	18	
18	D. L. & W.....	90-lb.	3.6	5.6	.....	.....	13	
19	A. S. C. E.....	85-lb.	3.3	5.8	D	L	12	
20	A. S. C. E.....	100-lb.	3.3	6.2	D	L	11	
21	Santa Fe.....	90-lb.	2.4	1.9	.....	.....	19	
22	Mo. Pac.....	85-lb.	2.2	20.2	D	L	3	
23	C. S.....	75-lb.	1.0	2.1	T	H	17	
24	A. S. C. E.....	75-lb.	0.2	3.3	D	L	16	

Bessemer with Various Alloys

								Alloy
1	A. S. C. E.....	100-lb.	73.5	.....	D	L	.....	Ferro Titanium.
2	A. S. C. E.....	90-lb.	56.9	2.8	D	L	2	Ferro Titanium.
3	G. N.....	90-lb.	19.5	.....	T	L	.....	Ferro Titanium.
4	A. R. A. "B".....	90-lb.	12.5	.....	D	L	.....	Ferro Titanium.
5	N. Y. N. H. & H....	100-lb.	10.0	.....	D	H	.....	Mayari.
6	A. S. C. E.....	85-lb.	6.0	15.7	D	L	1	Nickel.
7	Dudley.....	100-lb.	2.3	.....	T	H	.....	Ferro Titanium.
8	Dudley.....	80-lb.	1.2	.....	T	H	.....	Ferro Titanium.
9	A. R. A. "A".....	90-lb.	0.7	.....	T	H	.....	Ferro Titanium.

Open-Hearth with Various Alloys.

1	A. R. A. "B".....	90-lb.	812.7	565.3	D	L	1	Nickel Chrome.
2	A. S. C. E.....	90-lb.	578.4	36.9	D	L	2	Nickel Chrome.
3	D. L. & W.....	91-lb.	331 9	.....	.....	.....	.....	Nickel Chrome.
4	L. V. R. R.....	110-lb.	26.6	.....	.....	.....	.....	Ferro Titanium.
5	A. S. C. E.....	100-lb.	7.1	.....	D	L	.....	Ferro Titanium.
6	A. R. A. "A".....	100-lb.	2.3	.....	T	H	.....	Ferro Titanium.

Diagram No. 4—Comparison between different sections of rail, Open-mer steel.

The 76-lb. section should be neglected on account of the small quantity.

Note that the 72, 78, 80, 85 and 95-lb. sections give better results than the 90 and 100-lb. sections. If the quality of the material was the same, in all cases, better results would be expected from the 100-lb. sections, because, as a rule, the 100-lb. sections in general use are of better design than the other sections.

Diagram No. 2—Comparison between different weights of rail, Open-Hearth steel.

From this diagram it will be seen that 80-lb. sections, Open-Hearth, show the poorest results. We are unable to explain why the 80-lb. rails of Open-Hearth steel should give so much poorer results than the 80-lb. of Bessemer steel (see Diagram No. 1). When we compare this diagram with the same diagram of last year, it will be seen that the 80-lb. rail this year shows up worse than last year, the rate last year being 27.3 per 10,000 tons against 42.3 per 10,000 tons this year. The 80-lb. Bessemer shows a rate of 19.6 this year against 25.0 per 10,000 tons last year.

The 141-lb. section is a street rail and should be excluded. A small amount of 135-lb. rail is being used as an experiment.

Diagram No. 3—Comparison between different sections of rail, Bessemer steel.

A wide difference in results between different sections of same weight is shown.

Comparing Diagrams 3 and 4, the results do not show uniformity. Why should A. R. A. "A," 100-lb., show bad results in Bessemer steel and good results in the Open-Hearth steel?

Excluding P. R. R., 100-lb., Open-Hearth, why should the New Haven section show worse than A. R. A. section in Open-Hearth?

Why should A. R. A. "A," 100-lb., show so badly (77.1 failures per 10,000 tons, mostly in the head), when compared with Dudley, 100-lb. (34.0 failures per 10,000 tons, mostly breakages)? Last year the A. R. A. "A," 100-lb., showed a rate of 33.1 per 10,000 tons, whereas Dudley, 100-lb., showed 50.6 per 10,000 tons. The only answer at the present time is the lack of uniformity in the manufactured product.

Diagram No. 4—Comparison between different sections of rail, Open-Hearth steel.

Shows a wide difference in results from different sections of same weights.

The conclusion is the same as given in connection with Diagram No. 3.

Diagram No. 5 is a new one showing performance of mills and order of superiority for the year.

This diagram shows a uniformity of results in different sections from some mills, and a wide variation in results in different sections from other mills.

Ninety-pound sections show badly when rolled by Bethlehem, Cambria, Carnegie or Illinois South Works, and good when rolled by the Colorado, Gary, Lackawanna, Maryland, Pennsylvania and Tennessee.

Diagram No. 6 shows graphically the results for three years from different weights of rail, Bessemer steel.

Diagram No. 7 shows similar information for Open-Hearth steel.

Table No. 6 has been compiled for the purpose of showing the very great variation in the rate of rail failures for different sections and different weights, under as nearly similar conditions as could be obtained from the reports.

A. R. A. "A," 100-lb., rail failures varied in 1910 from 13 per 10,000 tons to 117.3 per 10,000 tons; in 1911, from 19.2 per 10,000 tons to 154.1 per 10,000 tons.

One hundred pound, A. R. A. "B," note that the rail furnished by the Maryland Steel Company for the Chesapeake & Ohio showed no failures in 1910 and 1911, whereas the rail furnished by the Illinois Steel Company for the same road showed rail failures at the rate of 2.7 per 10,000 tons and 0.9 per 10,000 tons, respectively.

One hundred pound, A. S. C. E., note variation in performance for the Illinois and Lackawanna rails on the C. B. & Q. and Grand Trunk railroads.

One hundred pound, P. S., note variation in performance of Carnegie rail on the Northwest and Southwest Systems of the Lines West of Pittsburgh.

Ninety-five-pound, B. & A., note the failures of Bethlehem rail rolled for the Boston & Albany Railroad.

Note the failures in 90-lb., A. R. A. "A," on the B. & O. Railroad from Illinois and Carnegie steel companies' rails.

Note the failures on the B. & O. of 90-lb., A. R. A. "B," from Carnegie, Cambria and Maryland mills, also, note the variation on the B. & O. from the Chesapeake & Ohio for 90-lb., A. R. A. "B," rails.

Note variation in performance of rails for the same roads, 90-lb., A. S. C. E. rail.

Variations similar to those mentioned above are found which cannot be explained by difference in section, or by difference in chemistry, or difference in railroad conditions, but must be attributed to variations in the performance of different mills, and also variations in the performance of the same mill at different times.

TABLE No. 6—COMPARISONS FROM REPORTS OF RAIL FAILURES TO THE A. R. E. A. FOR THE YEAR ENDING OCTOBER 31, 1911.

Bessemer Steel.

Year Laid.	Tons Laid.	Manufacturer	Carbon	Weight	Section	Railroad	Failures.		Remarks
							Last Year.	This Year.	
1909.....	2,121..	Carnegie.....	.46-.56	100-lb.	A. R. A. "A".....	B. & O.....	51.9	147.6	
1909.....	1,437..	Maryland.....	.58-.68	100-lb.	A. R. A. "A".....	C. R. R. of N. J.....	13.0	21.0	Low carbon rails show higher rate of failure than high carbon rail.
1909.....	1,643..	Carnegie.....	.45-.55	100-lb.	A. R. A. "A".....	P. L. W., N. W. S.....	30.4	18.2	
1909.....	1,535..	Carnegie.....	.45-.55	100-lb.	A. R. A. "A".....	P. L. W., S. W. S.....	117.3	254.1	
1910.....	11,000..	Illinois.....	.47	100-lb.	A. R. A. "B".....	C. & O.....	2.7	0.9	High carbon, low phosphorus .06, shows better than low carbon, high phosphorus .09.
1910.....	1,000..	Maryland.....	.50	100-lb.	A. R. A. "B".....	C. & O.....	.....	.....	
1907.....	2,055..	Illinois.....	.48-.58	100-lb.	A. S. C. E.....	C. B. & Q.....	228.7	253.0	Same carbon, different mills and roads, wide variation in results.
1907.....	6,138..	Lackawanna.....	.48-.58	100-lb.	A. S. C. E.....	Grand Trunk.....	25.0	55.0	
1909-1911..	26,773..	Carnegie.....	.45-.55	100-lb.	P. S.....	P. L., N. W. S.....	11.1	16.4	Same chemistry, same mill, same road, wide variation in results.
1909-1911..	16,402..	Carnegie.....	.45-.55	100-lb.	P. S.....	P. L., S. W. S.....	24.5	14.6	
1891-1911..	16,000..	Bethlehem.....	.60	95-lb.	B. & A.....	Boston & Albany.....	67.5	35.0	Different mills, same road, wide variation in results.
1893-1911..	45,678..	Lackawanna.....	.60	95-lb.	B. & A.....	Boston & Albany.....	21.0	15.5	
1908-1911..	15,457..	Illinois.....	.45-.55	90-lb.	A. R. A. "A".....	B. & O.....	19.0	24.0	Different mills, same road, wide variation in results.
1909-1911..	6,829..	Carnegie.....	.45-.55	90-lb.	A. R. A. "A".....	B. & O.....	177.0	98.5	
1908-1911..	36,935..	Carnegie.....	.45-.55	90-lb.	A. R. A. "B".....	B. & O.....	304.0	246.0	
1909-1911..	7,712..	Cambria.....	.45-.55	90-lb.	A. R. A. "B".....	B. & O.....	74.0	114.0	
1909-1911..	12,135..	Maryland.....	.45-.55	90-lb.	A. R. A. "B".....	B. & O.....	41.0	45.0	Same weight, chemistry and section, wide variation in results from different mills from same roads.
1910-1911..	11,000..	Maryland.....	.43-.53	90-lb.	A. R. A. "B".....	C. & O.....	2.7	5.4	
1909-1911..	15,349..	Carnegie.....	.45-.55	90-lb.	A. R. A. "B".....	Nor. Pac.....	33.0	43.7	
1909-1911..	18,172..	Illinois.....	.45-.55	90-lb.	A. R. A. "B".....	Nor. Pac.....	3.1	9.9	
1898-1911..	12,403..	Carnegie.....	.45-.53	90-lb.	A. S. C. E.....	B. R. & P.....	51.3	61.0	Variations in mills. Other conditions uniform.
1898-1911..	16,670..	Lackawanna.....	.45-.53	90-lb.	A. S. C. E.....	B. R. & P.....	37.3	53.0	
1903-1909..	28,836..	Maryland.....	.45-.60	90-lb.	A. S. C. E.....	C. R. R. of N. J.....	77.0	26.7	Low carbon not as good as high carbon. Same phosphorus, different mills.
1904-1907..	18,835.	Lackawanna.....	.54-.64	90-lb.	A. S. C. E.....	C. R. R. of N. J.....	56.0	23.3	
1906-1910..	84,435..	Illinois.....	.50-.60	90-lb.	A. S. C. E.....	C. C. C. & St. L.....	81.0	76.6	Same chemistry, same road, wide difference in results.
1905-1910..	27,400..	Carnegie.....	.50-.60	90-lb.	A. S. C. E.....	C. C. C. & St. L.....	237.0	100.0	
1906-1911..	55,275..	Lackawanna.....	.45-.58	90-lb.	A. S. C. E.....	Erie.....	13.8	17.0	
1906-1911..	78,445..	Carnegie.....	.45-.58	90-lb.	A. S. C. E.....	Erie.....	99.0	93.0	Different results from different mills.
1906-1911..	18,184..	Illinois.....	.45-.58	90-lb.	A. S. C. E.....	Erie.....	130.0	49.0	
1902-1909..	8,830..	Maryland.....	.45-.55	90-lb.	A. S. C. E.....	Lehigh Valley.....	122.3	23.8	
1903-1909..	6,398..	Cambria.....	.45-.55	90-lb.	A. S. C. E.....	Lehigh Valley.....	76.0	118.8	Same as above.
1905-1910..	54,500..	Cambria.....	.50-.64	90-lb.	A. S. C. E.....	Phila. & Reading.....	56.8	29.3	
1905-1910..	8,152..	Carnegie.....	.50-.64	90-lb.	A. S. C. E.....	Phila. & Reading.....	25.8	19.6	Same as above.
1905-1911..	11,819..	Lackawanna.....	.50-.64	90-lb.	A. S. C. E.....	Phila. & Reading.....	19.4	13.4	
1905-1911..	35,956..	Carnegie.....	.50-.60	90-lb.	C. S.....	Union Pacific.....	113.8	98.3	
1906-1910..	37,838..	Illinois.....	.50-.60	90-lb.	C. S.....	Union Pacific.....	51.5	48.1	Same as above.
1904-1909..	81,107..	Illinois.....	.48-.58	85-lb.	A. R. A. "A".....	A. T. & S. F.....	31.0	48.9	
1903-1907..	23,876..	Cambria.....	.48-.58	85-lb.	A. R. A. "A".....	A. T. & S. F.....	52.0	25.1	Same chemistry, same section, same road, different mills.
1904-1909..	51,002..	Maryland.....	.48-.58	85-lb.	A. R. A. "A".....	A. T. & S. F.....	20.8	30.1	
1902-1908..	168,000..	Carnegie.....	.45-.60	85-lb.	A. S. C. E.....	B. & O.....	54.0	53.5	
1902-1908..	52,692..	Maryland.....	.45-.55	85-lb.	A. S. C. E.....	B. & O.....	25.0	27.7	Different mills, different chemistry, same section, same road.
1902-1907..	56,695..	Cambria.....	.485-.502	85-lb.	A. S. C. E.....	B. & O.....	23.0	20.8	

1903-1908..	12,875..	Cambria.....	.45-.55	85-lb.	A. S. C. E.....	G. R. & I.....	67.7	44.6	Same mill, different chemistry, same road, different location.
1903-1907..	5,278..	Cambria.....	.40-.50	85-lb.	A. S. C. E.....	G. R. & I.....	1.9	1.9	
1901-1908..	94,500..	Maryland.....	.55-.58	85-lb.	A. S. C. E.....	Norfolk & Western.....	4.0	3.0	
1903-1908..	28,000..	Cambria.....	.55-.58	85-lb.	A. S. C. E.....	Norfolk & Western.....	10.0	1.8	Different mills, same chemistry and section, same road.
1901-1908..	86,500..	Carnegie.....	.55-.58	85-lb.	A. S. C. E.....	Norfolk & Western.....	15.0	2.9	
1899-1907..	170,439..	Carnegie.....	.55	85-lb.	A. S. C. E.....	P. L., N. W. S.....	47.3	36.0	Different mills, same chemistry and section, same road.
1899-1904..	12,246..	Illinois.....	.40-.55	85-lb.	A. S. C. E.....	P. L., N. W. S.....	4.1	8.0	
1892-1898..	55,370..	Carnegie.....	.30-.50	85-lb.	P. R. R.....	P. L., N. W. S.....	39.9	44.9	
1892-1898..	21,060..	Illinois.....	.30-.50	85-lb.	P. R. R.....	P. L., N. W. S.....	9.5	5.2	Different mills, same chemistry and section, same road.
1895-1898..	20,386..	Carnegie.....	.30-.50	85-lb.	P. R. R.....	P. L., S. W. S.....	35.8	37.8	
1895-1898..	8,173..	Illinois.....	.30-.50	85-lb.	P. R. R.....	P. L., S. W. S.....	7.3	8.6	
1909-1911..	2,798..	Cambria.....	.45-.55	85-lb.	P. S.....	G. R. & I.....	9.6	3.6	Same mill, chemistry, section and road, different locations.
1909-1911..	2,895..	Cambria.....	.45-.55	85-lb.	P. S.....	G. R. & I.....	17.7	20.7	
1909-1911..	7,660..	Carnegie.....	.50	85-lb.	P. S.....	P. L., N. W. S.....	168.0	156.6	
1909-1911..	2,321..	Illinois.....	.50	85-lb.	P. S.....	P. L., N. W. S.....	.....	4.3	Different mills. Other items same.
1900-1903..	20,790..	Carnegie.....	.....	80-lb.	A. S. C. E.....	Central Vermont.....	7.4	85.1	
1904-1910..	8,668..	Lackawanna.....	.....	80-lb.	A. S. C. E.....	Central Vermont.....	14.7	418.7	Same as above.
1904-1905..	11,550..	Lackawanna.....	.48-.58	80-lb.	A. S. C. E.....	C. C. C. & St. L.....	70.0	21.7	Different mills and chemistry Same road.
1903.....	5,250..	Illinois.....	.43-.53	80-lb.	A. S. C. E.....	C. C. C. & St. L.....	13.0	34.3	
1902-1906..	14,059..	Maryland.....	.55	80-lb.	A. S. C. E.....	G. H. & S. A*.....	2.8	2.1	
1901-1907..	46,403..	Carnegie.....	.55	80-lb.	A. S. C. E.....	G. H. & S. A.....	36.0	61.8	Different mills. Other items same.
1903-1905..	6,189..	Pennsylvania.....	.43-.53	80-lb.	A. S. C. E.....	Rock Island.....	19.3	24.2	
1902-1906..	15,984..	Maryland.....	.43-.58	80-lb.	A. S. C. E.....	Rock Island.....	8.4	6.3	Same as above.
1901-1905..	47,000..	Maryland.....	.48-.58	80-lb.	A. S. C. E.....	Southern.....	14.5	2.1	Different mills, same road. Note difference between high and low carbon.
1900-1905..	17,000..	Cambria.....	.48-.58	80-lb.	A. S. C. E.....	Southern.....	22.4	1.7	
1903-1907..	16,614..	Carnegie.....	.45-.55	80-lb.	A. S. C. E.....	Southern.....	36.0	27.1	
1902-1903..	8,555..	Maryland.....	.....	80-lb.	A. S. C. E.....	So. Pac. (east of Sparks)	9.72	4.6	
1902-1903..	10,934..	Carnegie.....	.....	80-lb.	A. S. C. E.....	So. Pac. (east of Sparks)	3.66	7.3	Different mills and chemistry. Note difference between high and low carbon.
1899-1907..	54,222..	Illinois.....	.46-.50	80-lb.	A. S. C. E.....	Union Pacific.....	35.5	19.3	
1901-1908..	64,437..	C. F. & I.†.....	.49-.57	80-lb.	A. S. C. E.....	Union Pacific.....	39.3	29.0	
1909-1911..	5,490..	Pennsylvania.....	.70-.85	100-lb.	A. R. A. "A".....	C. R. R. of N. J.....	6.0	5.4	Different mills. Other items same
1910-1911..	14,561..	Bethlehem.....	.70-.85	100-lb.	A. R. A. "A".....	C. R. R. of N. J.....	2.0	55.6	
1910-1911..	3,967..	Maryland.....	.70-.80	100-lb.	A. R. A. "B".....	B. & O.....	.....	30.2	Same as above.
1910-1911..	3,341..	Cambria.....	.70-.80	100-lb.	A. R. A. "B".....	B. & O.....	.....	6.0	
1910-1911..	1,966..	Bethlehem.....	.70-.80	100-lb.	A. R. A. "B".....	B. & O.....	.....	51.0	
1911.....	3,369..	Lackawanna.....	.70-.83	100-lb.	D. L. & W.....	D. L. & W.....	.....	.....	Same as above.
1911.....	1,788..	Pennsylvania.....	.70-.83	100-lb.	D. L. & W.....	D. L. & W.....	.....	.....	
1911.....	7,613..	Bethlehem.....	.70-.83	100-lb.	D. L. & W.....	D. L. & W.....	.....	.....	
1908-1911..	16,272..	Pennsylvania.....	.71-.90	100-lb.	N. Y. N. H. & H...	N. Y. N. H. & H.....	1.0	39.0	High rate of failures in the rail. Reported with lower carbon.
1908-1910..	14,281..	Bethlehem.....	.70-.80	100-lb.	N. Y. N. H. & H...	N. Y. N. H. & H.....	40.0	21.0	
1908-1911..	4,970..	Bethlehem.....	.66-.75	100-lb.	P. S.....	Penna East.....	35.0	42.0	
1907-1911..	30,997..	Cambria.....	.69-.75	100-lb.	P. S.....	Penna. East.....	10.0	16.0	
1909-1911..	10,966..	Carnegie.....	.69	100-lb.	P. S.....	Penna. East.....	14.0	5.0	
1909-1911..	5,023..	Lackawanna.....	.68-.69	100-lb.	P. S.....	Penna. East.....	53.0	30.0	
1907-1911..	2,197..	Maryland.....	.66-.69	100-lb.	P. S.....	Penna. East.....	19.0	18.0	
1908-1911..	17,023..	Pennsylvania.....	.69-.72	100-lb.	P. S.....	Penna. East.....	12.0	12.0	
1909-1911..	12,548..	Carnegie.....	.62-.75	100-lb.	P. S.....	Penna. N. W. S.....	4.8	6.3	
1909-1911..	20,510..	Illinois.....	.62-.75	100-lb.	P. S.....	Penna. N. W. S.....	8.3	11.2	
1909-1911..	96,200..	Illinois.....	.62-.75	90-lb.	A. R. A. "A".....	C. B. & Q.....	18.5	16.3	
1909-1911..	73,500..	C. F. & I.†.....	.55-.68	90-lb.	A. R. A. "A".....	C. B. & Q.....	1.6	1.6	

*Galveston, Harrisburg & San Antonio Ry. †Colorado Fuel & Iron.

Tables Nos. 7, 7-a and 7-b have been compiled for the purpose of showing the rate of failures for the different sections. Weights and manufacturers classified according to position of rail in ingot.

Table 7 contains the information furnished by individual roads.

Table 7-a contains summaries arranged according to process of manufacture and sections.

Table 7-b contains summaries arranged according to process of manufacture and the mill.

The tables need little comment. They show plainly that the weight and section of rail have practically no effect on the rate of failure of the rails, when classified according to position in ingot.

In the case of Bessemer rails, the larger portion (nearly 50 per cent.) of the failures occurred in the "A" rail. The P. R. R. section shows a much lower rate of failures for the "A" rails, but this is accounted for by the fact that no rails of this section have been purchased since 1908, and that a very large portion of the poor rails have been weeded out.

In regard to Open-Hearth rail, it is to be noted that the failures are more uniformly distributed through the ingot. The rate of failure in the "A" rail is a little higher than the others, but the failures in the Open-Hearth rail seem to be more consistent than in the Bessemer rail, showing a much more uniform product than when made by the Bessemer process.

Referring to the Bessemer Ferro Titanium, Open-Hearth Ferro Titanium and other alloy rails, it is to be noted that the rate of failure is lower in the "A" rails than in the rails made by the regular Bessemer and Open-Hearth processes. This is believed to be due to the greater care that has been exercised in the manufacture of these rails made of special composition.

The tables also contain a summary, showing the performances of the different manufacturers in regard to this subject.

The statistics show a high rate of failure in the B, C, D and E rails in many individual cases.

TABLE No. 7—SUMMARY OF NUMBER OF BESSEMER RAIL FAILURES ACCORDING TO POSITION IN THE INGOT.

Wt.	Section	Manufacturer	Position in Ingot						Unknown	Total	Railroad
			A	B	C	D	E	F, etc.			
100	A. R. A. "A"	Carnegie	5	13	12				3	33	Baltimore & Ohio
100	A. R. A. "A"	Maryland	8	3	1	1			1	14	Baltimore & Ohio
100	A. R. A. "A"	Illinois	1							1	Baltimore & Ohio
100	A. R. A. "A"	Maryland	1		1	1				3	Central of New Jersey
100	A. R. A. "A"	Carnegie		1	1				1	3	Penna. Lines West—N. W. System
100	A. R. A. "A"	Carnegie		31		3			5	39	Penna. Lines West—S. W. System
100	A. R. A. "A"	Carnegie		15	25	1	1		9	51	Pittsburgh & Lake Erie
100	A. R. A. "B"	Maryland	77	7	14	11	8		8	125	Baltimore & Ohio
100	A. R. A. "B"	Cambria	8	1	1	2			6	18	Baltimore & Ohio
100	A. R. A. "B"	Illinois					1			1	Chesapeake & Ohio
100	A. R. A. "B"	Carnegie		5	1		1		1	8	Pittsburgh & Lake Erie
100	A. S. C. E.	Maryland	20	2	12	7	7		158	206	Baltimore & Ohio
100	A. S. C. E.	Cambria	6	1		1	1		37	46	Baltimore & Ohio
100	A. S. C. E.	Illinois	23	1	5	1			22	52	Chicago, Burlington & Quincy
100	Dudley	Lackawanna	40	16	18				32	106	Boston & Albany
100	Dudley	Lackawanna	58	54	25	6	2	1	269	415	New York Central & Hudson River
100	Dudley	Carnegie	4	1		1			22	28	New York Central & Hudson River
100	P. R. R.	Maryland	5	7		1			8	21	Cumberland Valley
100	P. R. R.	Maryland	1	7	1	1	4	4	201	219	Penna. Lines East
100	P. S.	Cambria	12	6		10	8		6	42	Penna. Lines East
100	P. S.	Lackawanna	9	1	2				1	13	Penna. Lines East
100	P. S.	Maryland	12	2	18	4	3		2	41	Penna. Lines East
100	P. S.	Carnegie		23	8		1		12	44	Penna. Lines West—N. W. System
100	P. S.	Illinois	1							1	Penna. Lines West—N. W. System
100	P. S.	Cambria	2	1	2	2	1	1		9	Penna. Lines West—N. W. System
100	P. S.	Carnegie		19	2				3	24	Penna. Lines West—S. W. System
100	P. S.	Illinois	1							1	Penna. Lines West—S. W. System
100	P. S.	Cambria	16	1	2	1	2	2	1	25	Penna. Lines West—S. W. System
100	P. & R.	Maryland	24	4	7	6	1			42	Philadelphia & Reading
100	P. & R.	Carnegie	11	1	1		1			14	Philadelphia & Reading
90	A. R. A. "A"	Carnegie	39	3	26	1				69	Baltimore & Ohio
90	A. R. A. "A"	Illinois	16	7	6	1			6	36	Baltimore & Ohio
90	A. R. A. "A"	Illinois		4	1	1				6	Oregon-Wash. R. R. & Nav. Co.
90	A. R. A. "A"	Illinois		3	16	12				31	Oregon Short Line
90	A. R. A. "A"	Illinois	13	3	4	6		1		27	Southern Pacific
90	A. R. A. "B"	Carnegie	367	106	302	59	9	4	64	911	Baltimore & Ohio
90	A. R. A. "B"	Maryland	59	11	2	5	6		9	92	Baltimore & Ohio
90	A. R. A. "B"	Illinois	6	3	1					10	Baltimore & Ohio
90	A. R. A. "B"	Cambria	30	30	9	18	15	5	16	123	Baltimore & Ohio
90	A. R. A. "B"	Maryland	1			1	4			6	Chesapeake & Ohio
90	A. R. A. "B"	Illinois	4	2	3	2	1		6	18	Northern Pacific
90	A. R. A. "B"	Lackawanna	6	1	1	3			5	16	Northern Pacific
90	A. R. A. "B"	Carnegie	16	3	18	4			26	67	Northern Pacific
90	A. S. C. E.	Carnegie	1							1	Chesapeake & Ohio

TABLE No. 7—SUMMARY OF NUMBER OF BESSEMER RAIL FAILURES ACCORDING TO POSITION IN THE INGOT—CONTINUED.

Wt.	Section	Manufacturer	Position in Ingot						Unknown	Total	Railroad
			A	B	C	D	E	F, etc.			
90	A. S. C. E.	Maryland	11	10	9	1	5	.....	41	77	Central of New Jersey
90	A. S. C. E.	Lackawanna	6	2	.....	1	.....	.....	35	44	Central of New Jersey
90	A. S. C. E.	Carnegie	6	.....	.....	.....	.....	.....	17	23	Hocking Valley
90	A. S. C. E.	Lackawanna	5	5	5	15	8	.....	232	270	Lehigh Valley
90	A. S. C. E.	Maryland	57	19	12	12	15	.....	35	150	Philadelphia & Reading
90	C. S.	Illinois	38	8	10	1	.....	.....	8	65	Illinois Central
90	G. N.	Illinois	6	2	15	4	3	10	47	87	Great Northern
90	G. N.	Lackawanna	19	41	37	38	9	1	16	161	Great Northern
90	G. N.	Maryland	21	9	1	2	.....	.....	.....	33	Great Northern
90	G. N.	Cambria	27	7	7	23	12	5	2	83	Great Northern
85	A. S. C. E.	Carnegie	45	8	35	11	6	.....	820	925	Baltimore & Ohio
85	A. S. C. E.	Maryland	43	7	10	6	4	.....	83	153	Baltimore & Ohio
85	A. S. C. E.	Cambria	5	1	4	.....	1	.....	115	126	Baltimore & Ohio
85	A. S. C. E.	Carnegie	89	.....	.....	.....	.....	.....	43	132	Chicago & Eastern Illinois
85	A. S. C. E.	Illinois	7	4	6	6	.....	2	213	238	Illinois Central
85	A. S. C. E.	Carnegie	3	2	1	.....	.....	.....	19	25	Norfolk & Western
85	A. S. C. E.	Maryland	4	.....	.....	.....	.....	.....	24	28	Norfolk & Western
85	A. S. C. E.	Illinois	39	11	17	13	6	.....	1864	1950	Northern Pacific
85	A. S. C. E.	Lackawanna	34	26	33	37	1	1	520	652	Northern Pacific
85	A. S. C. E.	Illinois	6	7	2	3	1	.....	2	21	Rock Island
85	C. B. & Q.	Illinois	220	37	45	45	8	11	287	653	Chicago, Burlington & Quincy
85	C. B. & Q.	Carnegie	3	1	6	.....	2	2	89	103	Chicago, Burlington & Quincy
85	C. B. & Q.	Col. Fuel & Iron	5	6	4	3	2	.....	92	112	Chicago, Burlington & Quincy
85	P. R. R.	Maryland	.....	2	.....	.....	2	1	1	6	New York, Philadelphia & Norfolk
85	P. R. R.	Maryland	3	6	4	1	8	1	124	147	Penna. Lines East
85	P. S.	Maryland	1	1	1	2	6	.....	.....	11	New York, Philadelphia & Norfolk
85	P. S.	Cambria	7	1	2	8	.....	2	3	23	Penna. Lines East
85	P. S.	Lackawanna	3	2	.....	.....	.....	.....	.....	5	Penna Lines East.
85	P. S.	Maryland	8	1	6	2	1	.....	.....	18	Penna. Lines East
85	P. S.	Carnegie	45	8	60	2	.....	2	3	120	Penna. Lines West—N. W. System
85	P. S.	Illinois	.....	1	.....	.....	.....	.....	.....	1	Penna. Lines West—N. W. System
85	P. S.	Cambria	.....	.....	1	2	1	.....	2	6	Penna. Lines West—N. W. System
85	P. S.	Carnegie	58	17	42	29	.....	7	8	161	Penna. Lines West—S. W. System
85	P. S.	Illinois	15	1	3	.....	.....	1	3	23	Penna. Lines West—S. W. System
85	P. S.	Cambria	.....	.....	.....	.....	2	1	2	5	Penna. Lines West—S. W. System
85	P. S.	Carnegie	79	5	57	10	.....	.....	4	155	Cleveland, Akron & Cincinnati
80	A. S. C. E.	Illinois	2	2	8	2	.....	.....	76	90	Lake Shore & Michigan Southern
80	Dudley	Lackawanna	18	19	14	3	.....	.....	83	137	New York Central & Hudson River
75	A. S. C. E.	Illinois	4	1	2	.....	1	.....	17	25	Illinois Central
75	A. S. C. E.	Maryland	.....	2	.....	.....	.....	.....	4	6	Norfolk & Western
75	A. S. C. E.	Carnegie	8	1	.....	.....	.....	.....	54	63	Toledo, St. Louis & Western
To	tal all Bessemer	.....	1853	682	1007	455	181	65	5928	10171	

TABLE No. 7—SUMMARY OF NUMBER OF OPEN-HEARTH RAIL FAILURES ACCORDING TO POSITION IN THE INGOT.

Wt.	Section	Manufacturer	Position in Ingot						Unknown	Total	Railroad
			A	B	C	D	E	F, etc.			
135	Special	Penna	7	6	3				14	30	Central of New Jersey
100	A. R. A "A"	Penna	1	1		1				3	Central of New Jersey
100	A. R. A. "A"	Bethlehem	10	40	8	9	8		6	81	Central of New Jersey
100	A. R. A. "A"	Illinois	1					1		2	Rock Island
100	A. R. A. "B"	Bethlehem	1	1	3	3			2	10	Baltimore & Ohio
100	A. R. A. "B"	Maryland	10	3	3	2				18	Norfolk & Western
100	A. R. A. "B"	Illinois				1				1	Norfolk & Western
100	N. Y. N. H. & H.	Penna	19	14	15	9			7	64	New York, New Haven & Hartford
100	N. Y. N. H. & H.	Bethlehem	8	4	1	2	5	1	9	30	New York, New Haven & Hartford
100	P. S.	Penna		1	1					2	Cumberland Valley
100	P. S.	Bethlehem		2	2	6	5	2	4	21	Penna. Lines East
100	P. S.	Carnegie	1			2	1		1	5	Penna. Lines East
100	P. S.	Maryland	3	1						4	Penna. Lines East
100	P. S.	Cambria	13	11	5	8	6	5	2	50	Penna. Lines East
100	P. S.	Lackawanna	8	2	2				3	15	Penna. Lines East
100	P. S.	Penna	7	3	7	3				20	Penna. Lines East
100	P. S.	Carnegie		3			3	2	1	9	Penna. Lines West—N. W. System
100	P. S.	Illinois	5	2	3	4	3	5	1	23	Penna. Lines West—N. W. System
100	P. S.	Cambria		1	1					2	Penna. Lines West—N. W. System
100	P. S.	Cambria		1			1			2	Penna. Lines West—S. W. System
100	P. & R.	Penna	4	4	1	2			19	30	Philadelphia & Reading
90	A. R. A. "A"	Illinois		1			1	1	2	5	Baltimore & Ohio
90	A. R. A. "A"	Col. Fuel & Iron Co.	3	2	2				5	12	Chicago, Burlington & Quincy
90	A. R. A. "A"	Lackawanna	4	1	5	2		1	7	20	Chicago, Burlington & Quincy
90	A. R. A. "A"	Illinois	18	13	9	8	12	20	77	157	Chicago, Burlington & Quincy
90	A. R. A. "A"	Tenn. Coal & Iron		1	1			1		3	Galveston, Harrisburgh & San Antonio
90	A. R. A. "A"	Tenn. Coal & Iron	1							1	Houston & Texas Central
90	A. R. A. "A"	Tenn. Coal & Iron	1	1	1	1	1		1	6	Illinois Central
90	A. R. A. "A"	Illinois	3	1	1			1	1	7	Illinois Central
90	A. R. A. "A"	Tenn. Coal & Iron						1		1	Morgan's Louisiana & Texas
90	A. R. A. "A"	Col. Fuel & Iron		1						1	Oregon-Washington R. R. & Nav. Co
90	A. R. A. "A"	Col. Fuel & Iron	2	3	2	5			2	14	Oregon Short Line
90	A. R. A. "A"	Tenn. Coal & Iron	2	2	1	3				8	Southern Pacific
90	A. R. A. "A"	Illinois	1	18	6	8	1	25		59	Southern Pacific
90	A. R. A. "A"	Col. Fuel & Iron		1						1	Southern Pacific
90	A. R. A. "B"	Illinois	2		3		3		1	9	Baltimore & Ohio
90	A. R. A. "B"	Bethlehem	64	47	64	49	57	18	65	364	Baltimore & Ohio

TABLE No. 7—SUMMARY OF NUMBER OF OPEN-HEARTH RAIL FAILURES ACCORDING TO POSITION IN THE INGOT—CONTINUED.

Wt.	Section	Manufacturer	Position in Ingot						Unknown	Total	Railroad
			A	B	C	D	E	F, etc.			
90	A. R. A. "B"	Bethlehem	1		1					2	Chesapeake & Ohio
90	A. R. A. "B"	Carnegie			1	1	1		4	7	Hocking Valley
90	A. R. A. "B"	Illinois	9	3	12	6	5	11	25	71	Northern Pacific
90	A. S. C. E	Bethlehem	7	15	17	8	11	2	19	79	Central of New Jersey
90	A. S. C. E	Bethlehem	3	10	3	2	4		27	49	Delaware & Hudson
90	A. S. C. E	Bethlehem	46	22	30	34	24		122	278	Lehigh Valley
90	A. S. C. E	Lackawanna	1	2	2				8	13	Lehigh Valley
90	A. S. C. E	Carnegie	1	1					5	7	Lehigh Valley
90	A. S. C. E	Bethlehem		3	1	1			2	7	Philadelphia & Reading
90	C. S	Tenn. Coal & Iron	1	2	2	1	1	1		8	Illinois Central
90	D. L. & W	Bethlehem	1	12	8	12	16		67	116	Delaware, Lackawanna & Western
90	D. L. & W	Lackawanna	2	2		2				6	Delaware, Lackawanna & Western
90	G. N	Illinois	35	26	48	35	39	107	11	301	Great Northern
90	G. N	Lackawanna	8	1	1	4			1	15	Great Northern
90	G. N	Bethlehem	44	38	16	14	18	4	18	152	Great Northern
85	A. S. C. E	Illinois	5						4	9	Chicago & Eastern Illinois
85	A. S. C. E	Tenn. Coal & Iron	1		3	1			27	32	Illinois Central
85	A. S. C. E	Penna	3	2	2				7	14	Norfolk & Western
85	A. S. C. E	Bethlehem	12	7	1	1		1	4	26	Norfolk & Western
85	A. S. C. E	Carnegie	1	2	1				1	5	Norfolk & Western
85	A. S. C. E	Maryland					1			1	Norfolk & Western
85	A. S. C. E	Cambria	2	2	1		1			6	Norfolk & Western
85	A. S. C. E	Illinois	2	1	1		2			6	Rock Island
85	C. B. & Q	Bethlehem	3		1				15	19	Chicago, Burlington & Quincy
85	P. S	Bethlehem			1	7		1	3	12	Penna. Lines East
85	P. S	Maryland	1			1			2	4	Penna. Lines East
85	P. S	Cambria	5	1	6	5	4	2		23	Penna. Lines East
85	P. S	Lackawanna	5	1					1	7	Penna. Lines East
85	P. S	Penna	3	3					2	8	Penna. Lines East
85	P. S	Illinois	1	1	1	1	1		6	11	Penna. Lines—S. W. System
85	P. S	Carnegie			1	2	1	1		5	Cleveland, Akron & Cincinnati
85	P. S	Illinois	4	4	5	2		2		17	Vandalia
80	A. S. C. E	Tenn. Coal & Iron	4	4	2	1		4		15	Louisville & Nashville
80	N. Y. N. H. & H	Penna							4	4	New York, New Haven & Hartford
80	N. Y. N. H. & H	Bethlehem	5		1			2	1	9	New York, New Haven & Hartford
80	N. Y. N. H. & H	Maryland	1							1	New York, New Haven & Hartford
	Total all Open-Hearth		416	357	319	269	236	222	616	2435	

TABLE No. 7—SUMMARY OF NUMBER OF RAIL FAILURES ACCORDING TO POSITION IN THE INGOT.

Wt.	Section	Steel	Manufacturer	Position in Ingot						Unknown	Total	Railroad
				A	B	C	D	E	F, etc.			
100	Dudley	Bessemer Ferro Tit	Lackawanna	12	1	5					18	Boston & Albany
100	Dudley	Bessemer Ferro Tit	Lackawanna	10	7	7				8	32	New York Central & Hudson River
90	A. S. C. E	Bessemer Ferro Tit	Lackawanna	5	6	2	11		5	1	30	Central of New Jersey
90	A. S. C. E	Bessemer Ferro Tit	Lackawanna	4	3	1				13	21	Lehigh Valley
90	G. N	Bessemer Ferro Tit	Lackawanna	2			2				4	Great Northern
80	Dudley	Bessemer Ferro Tit	Lackawanna	36	39	56	101			32	264	New York Central & Hudson River
80	A. S. C. E	Bessemer Ferro Tit	Lackawanna	1						1	2	Toledo, St. Louis & Western
110	L. V	Open-Hearth Ferro Tit	Bethlehem			4			1	1	6	Lehigh Valley
101	D. L. & W	Open-Hearth Ferro Tit	Bethlehem			1					1	Delaware, Lackawanna & Western
101	D. L. & W	Open-Hearth Ferro Tit	Lackawanna			1					1	Delaware, Lackawanna & Western
90	A. S. C. E	Open-Hearth Ferro Tit	Bethlehem	7	21	11	15	11		8	73	Lehigh Valley
90	A. S. C. E	Open-Hearth Ferro Tit	Carnegie	1							1	Lehigh Valley
91	D. L. & W	Open Hearth Ferro Tit	Bethlehem	4	18	25	22	13		151	233	Delaware, Lackawanna & Western
90	A. S. C. E	Open-Hearth Chrome Nickel	Bethlehem	246	133	208	106	144	5	130	972	Central of New Jersey
85	P. S	Open-Hearth Chrome Nickel Mayari	Penna	1			1				2	Penna. Lines—S. W. System

TABLE No. 7-A—GENERAL SUMMARY OF NUMBER OF RAIL FAILURES ACCORDING TO POSITION IN THE INGOT.
(Percentages Based on Known Failures.)

Wt.	Section	Steel	Manufacturer	A	B	C	D	E	F, etc.	Unknown	Total
100	A. R. A. "A"	Bessemer	Various	15 12%	63 50.4%	40 32%	6 4.8%	1 0.8%		19	144
100	A. R. A. "B"	Bessemer	Various	85 62%	13 9.5%	16 11.7%	13 9.5%	10 7.3%		15	152
100	A. S. C. E.	Bessemer	Various	49 56.4%	4 4.6%	17 19.5%	9 10.3%	8 9.2%		217	304
100	Dudley	Bessemer	Various	102 45.1%	71 31.4%	43 19.1%	7 3.1%	2 0.9%	1 0.4%	323	549
100	P. R. R.	Bessemer	Maryland	6 19.4%	14 45.1%	1 3.2%	2 6.5%	4 12.9%	4 12.9%	209	240
100	P. S.	Bessemer	Various	53 30.3%	53 30.3%	34 19.4%	17 9.7%	15 8.6%	3 1.7%	25	200
100	P. & R.	Bessemer	Various	35 62.5%	5 9.0%	8 14.3%	6 10.7%	2 3.5%			56
Total all 100-lb. Bessemer				345 41.2%	223 26.6%	159 19.0%	60 7.2%	42 5.1%	8 0.9%	808	1,645
90	A. R. A. "A"	Bessemer	Various	68 41.7%	20 12.3%	53 32.5%	21 12.9%		1 0.6%	6	169
90	A. R. A. "B"	Bessemer	Various	489 43.9%	156 13.9%	336 30.0%	92 8.2%	35 3.2%	9 0.8%	126	1,243
90	A. S. C. E.	Bessemer	Various	86 42.0%	36 17.6%	26 12.7%	29 14.1%	28 13.6%		360	565
90	C. S.	Bessemer	Illinois	38 66.7%	8 14.0%	10 17.5%	1 1.8%			8	65
90	G. N.	Bessemer	Various	73 24.4%	59 19.7%	60 20.1%	67 22.4%	24 8.1%	16 5.3%	65	364
Total all 90-lb. Bessemer				754 40.9%	279 15.2%	485 26.4%	210 11.4%	87 4.7%	26 1.4%	565	2,406
85	A. S. C. E.	Bessemer	Various	275 50.3%	66 12.1%	108 19.7%	76 13.8%	19 3.6%	3 0.5%	3,703	4,250
85	C. B. & Q.	Bessemer	Various	228 57%	44 11%	55 13.8%	48 12%	12 3%	13 3.2%	468	868
85	P. R. R.	Bessemer	Maryland	3 10.7%	8 28.6%	4 14.2%	1 3.5%	10 35.9%	2 7.1%	125	153
85	P. S.	Bessemer	Various	216 42.9%	37 7.4%	172 34.3%	55 10.9%	10 2.1%	13 2.4%	25	528
Total all 85-lb. Bessemer				722 48.8%	155 10.5%	339 22.9%	180 12.2%	51 3.5%	31 2.1%	4,321	5,799

80	A. S. C. E.	Bessemer	Illinois	2 14.3%	2 14.3%	8 57.1%	2 14.3%	.....	.....	76	90 .....
80	Dudley	Bessemer	Lackawanna	18 33.3%	19 35.2%	14 25.9%	3 5.6%	.....	.....	83	137 .....
Total all 80-lb. Bessemer				20 29.4%	21 30.9%	22 32.4%	5 7.3%	.....	.....	159	227 .....
75	A. S. C. E.	Bessemer	Various	12 63.2%	4 21.1%	2 10.5%	.....	1 5.2%	.....	75	94 .....
Total all Bessemer				1,853 43.7%	682 16.1%	1,007 23.7%	455 10.7%	181 4.3%	65 1.5%	5,928	10,171 .....
135	Special	Open-Hearth	Penna	7 43.8%	6 37.5%	3 18.7%	.....	.....	.....	14	30 .....
100	A. R. A. "A"	Open-Hearth	Various	12 15.0%	41 51.3%	8 10.0%	10 12.5%	8 10.0%	1 1.2%	6	86 .....
100	A. R. A. "B"	Open-Hearth	Various	11 40.8%	4 14.8%	6 22.2%	6 22.2%	.....	.....	2	29 .....
100	N. Y. N. H. & H.	Open-Hearth	Various	27 34.7%	18 23.1%	16 20.5%	11 14.1%	5 6.2%	1 1.4%	16	94 .....
100	P. S.	Open-Hearth	Various	37 26.2%	27 19.1%	21 14.9%	23 16.3%	19 13.5%	14 10.0%	12	153 .....
100	P. & R.	Open-Hearth	Various	4 36.4%	4 36.4%	1 9.1%	2 18.1%	.....	.....	19	30 .....
Total all 100-lb. Open-Hearth				91 27.0%	94 27.9%	52 15.4%	52 15.4%	32 9.5%	16 4.8%	55	392
90	A. R. A. "A"	Open-Hearth	Various	35 17.5%	45 22.5%	28 14.0%	27 13.5%	15 7.5%	50 25.0%	95	295 .....
90	A. R. A. "B"	Open-Hearth	Various	76 21.3%	50 14.1%	81 22.4%	56 15.7%	66 18.4%	29 8.1%	95	453 .....
90	A. S. C. E.	Open-Hearth	Various	58 23.0%	53 21.0%	53 21.0%	45 17.9%	39 15.9%	2 1.2%	183	433 .....
90	C. S.	Open-Hearth	T. C. & I.	1 12.5%	2 25.0%	2 25.0%	1 12.5%	1 12.5%	1 12.5%	.....	8 .....
90	D. L. & W.	Open-Hearth	Various	3 5.4%	14 25.5%	8 14.5%	14 25.5%	16 29.1%	.....	67	122 .....
90	G. N.	Open-Hearth	Various	87 19.9%	65 14.8%	65 14.8%	53 12.1%	57 13.0%	111 25.4	30	468 .....
Total all 90-lb. Open-Hearth				260 19.8%	229 17.4%	247 18.1%	196 15%	194 14.9%	193 14.8%	470	1,779 .....

TABLE No. 7-A—GENERAL SUMMARY OF NUMBER OF RAIL FAILURES ACCORDING TO POSITION IN THE INGOT—CONTINUED.
(Percentages Based on Known Failures).

Wt.	Section	Steel	Manufacturer	A	B	C	D	E	F, etc.	Unknown	Total
85	A. S. C. E.	Open-Hearth	Various	26 46.4%	14 25%	9 16.1%	2 3.6%	4 7.1%	1 1.8%	43	99 .....
85	C. B. & Q.	Open-Hearth	Bethlehem	3 75%	.....	1 25%	.....	.....	.....	15	19 .....
85	P. S.	Open-Hearth	Various	19 26%	10 13.7%	14 19.2%	18 24.7%	6 8.2%	6 8.2%	14	87 .....
Total 85-lb. Open Hearth				48 36.1%	24 18%	24 18.1%	20 15%	10 7.5%	7 5.3%	72	205 .....
80	A. S. C. E.	Open-Hearth	T. C. & I.	4 26.7%	4 26.7%	2 13.3%	1 6.6%	.....	4 26.7%	.....	15 .....
80	N. Y. N. H. & H.	Open-Hearth	Various	6 66.7%	....	1 11.1%	....	.....	2 22.2%	5	14 .....
Total 80-lb. Open-Hearth				10 41.7%	4 16.6%	3 12.5%	1 4.2%	.....	6 25%	5	29 .....
Total all Open-Hearth				416 22.9%	357 19.6%	319 17.5%	269 14.8%	236 13%	222 12.2%	616	2,435 .....
100	Dudley	Bessemer Ferro Tit.	Lackawanna	22 52.4%	8 19.0%	12 28.6%	.....	.....	.....	8	50 .....
90	A. S. C. E.	Bessemer Ferro Tit.	Lackawanna	9 24.3%	9 24.3%	3 8.1%	11 29.8%	.....	5 13.5%	14	51 .....
90	G. N.	Bessemer Ferro Tit.	Lackawanna	2 50%	....	....	2 50%	.....	.....	....	4 .....
80	Dudley	Bessemer Ferro Tit.	Lackawanna	36 15.5%	39 16.8%	56 24.2%	101 43.5%	.....	.....	32	264 .....
80	A. S. C. E.	Bessemer Ferro Tit.	Lackawanna	1 100%	....	....	....	.....	.....	1	2 .....
Total all Bessemer Ferro. Tit				71 22.4%	56 17.7%	71 22.4%	114 35.9%	.....	5 1.6%	55	372 .....

110	L. V.	Open-Hearth	Bethlehem	.....	4 80%	.....	.....	.....	1 20%	1	6
101	D. L. & W.	Ferro Tit. Open-Hearth	Bethlehem	.....	2 100%	.....	.....	.....	.....	.....	2
90	A. S. C. E.	Ferro Tit. Open-Hearth	Lackawanna Carnegie	8 12.1%	21 31.8%	11 16.7%	15 22.7%	11 16.7%	.....	8	74
		Ferro Tit.	Bethlehem						.....	.....	.....
Total all Open-Hearth Ferro Tit.				7 9.7 %	37 37.5%	11 15.3%	15 20.7%	11 15.3%	1 1.5%	9	81
91	D. L. & W.	Open-Hearth	Bethlehem	4 4.9%	18 21.9%	25 30.5%	22 26.8%	13 15.9%	.....	151	233
90	A. S. C. E.	Chrome Nickel Open-Hearth	Bethlehem	246 29.2%	133 15.8%	208 24.7%	106 12.6%	144 17.1%	5 0.6%	130	972
		Chrome Nickel								.....	.....
Total all Open-Hearth Chrome Nickel				250 27.1%	151 16.3%	233 25.2%	128 13.9%	157 17.0%	5 0.5%	281	1,205
85	P. S.	Open-Hearth	Penna	1 50%	.....	1 50%	.....	.....	.....	.....	2
		Mayari									.....

TABLE No. 7-B—GENERAL SUMMARY BY MANUFACTURERS OF NUMBER OF RAIL FAILURES CLASSIFIED ACCORDING TO POSITION IN INGOT.

(Percentages Based on Known Failures)

Manufacturer	Steel	Position in Ingot							
		A	B	C	D	E	F, etc.	Unknown	Total
Carnegie	Bessemer	779 43.5%	263 14.6%	597 33.2%	121 6.7%	21 1.2%	15 0.8%	1,203	2,999
Illinois	Bessemer	402 51.1%	97 12.4%	144 18.3%	97 12.3%	21 2.7%	25 3.2%	2,551	3,337
Maryland	Bessemer	356 50.9%	100 14.3%	99 14.2%	64 9.1%	74 10.6%	6 0.9%	699	1,398
Cambria	Bessemer	113 35.8%	49 15.5%	28 8.9%	67 21.2%	43 13.6%	16 5.0%	190	506
Lackawanna	Bessemer	198 31.6%	167 26.7%	135 21.6%	103 16.4%	20 3.2%	3 0.5%	1,193	1,819
Colorado Fuel & Iron Co.	Bessemer	5 25%	6 30%	4 20%	3 15%	2 10%		92	112
Total all Bessemer		1,853 43.7%	682 16.1%	1,007 23.7%	455 10.7%	181 4.3%	65 1.5%	5,928	10,171
Carnegie	Open-Hearth Ferro Titan	1 100%							1
Lackawanna	Bessemer Ferro Titan	70 22.1%	56 17.7%	71 22.6%	114 36.1%		5 1.6%	55	371
Lackawanna	Open-Hearth Ferro Titan		1 100%						1
Bethlehem	Open-Hearth Ferro Titan	7 9.9%	26 36.6%	11 15.5%	15 21.1%	11 15.5%	1 1.4%	9	80
Bethlehem	Open-Hearth Chrome Nickel	250 27.1%	151 16.3%	233 25.2%	128 13.9%	157 17%	5 0.5%	281	1,205
Penna	Open-Hearth Mayari	1 50%			1 50%				2

TABLE No. 7-B—GENERAL SUMMARY BY MANUFACTURERS OF NUMBER OF RAIL FAILURES CLASSIFIED ACCORDING TO POSITION IN INGOT

(Percentages Based on Known Failures)

Manufacturer	Steel	Position in Ingot							
		A	B	C	D	E	F, etc.	Unknown	Total
Carnegie	Open-Hearth	3 11.5%	6 23.1%	3 11.5%	5 19.3%	6 23.1%	3 11.5%	12	38 .....
Illinois	Open-Hearth	86 15.6%	70 12.7%	89 16.2%	65 11.8%	67 12.2%	173 31.5%	128	678 .....
Maryland	Open-Hearth	15 57.7%	4 15.4%	3 11.5%	3 11.5%	1 3.9%	.....	2	28 .....
Cambria	Open-Hearth	20 24.7%	16 19.8%	13 16.0%	13 16.0%	12 14.9%	7 8.6%	2	83 .....
Lackawanna	Open-Hearth	28 50%	9 16.1%	10 17.8%	8 14.3%	.....	1 1.8%	20	76 .....
Colorado Fuel & Iron	Open-Hearth	5 23.8%	7 33.3%	4 19.1%	5 23.8%	.....	.....	7	28 .....
Bethlehem	Open-Hearth	205 22.9%	201 22.5%	158 17.7%	148 16.6%	148 16.7%	31 3.6%	364	1,255 .....
Penna	Open-Hearth	44 36.1%	34 27.8%	29 23.8%	15 12.3%	.....	.....	53	175 .....
Tenn. Coal & Iron	Open-Hearth	10 21.7%	10 21.7%	10 21.7%	7 15.2%	2 4.5%	7 15.2%	28	74 .....
Total all Open-Hearth		416 22.9%	357 19.6%	319 17.5%	269 14.8%	236 13.0%	222 12.2%	616	2,435 .....

RECORD OF COMPARATIVE WEAR OF SPECIAL RAIL.

BALTIMORE & OHIO RAILROAD.

Several tests are reported as completed:

High Silicon rail (Car. .596, Mn. 1.11, Ph. .10, Sil. .69) on 8-degree curve at Hoblitzell, 7 out of 8 rails failed. The rail was too brittle.

Nickel Chrome rail on 4-degree 30-min. curve at Bloomington, manufactured by the Bethlehem Steel Company, compared with Bethlehem ordinary Open-Hearth; in two years and eight months showed 9.72 per cent. of head worn, against 18.91 per cent. for the ordinary Open-Hearth.

Nickel Chrome rail, manufactured by the Bethlehem Steel Company, on 9-degree 30-min. curve at Bloomington, showed 18.89 per cent. of head abraded in two years and eight months, against 31.77 per cent. of the head abraded for ordinary Open-Hearth rail. The Nickel Chrome rail shows good wearing quality but the rate of failure was excessively high.

Titanium Alloy Bessemer rail on 9-degree curve at Kesslers, shows in one year and four months slightly better results than Open-Hearth rail.

Nickel Chrome rail on 7-degree 57-min. curve at Bloomington, shows 15.1 per cent. of the head abraded in two years and eight months, against 22.4 per cent. abradded for Bethlehem Open-Hearth rail. The Nickel Chrome rail shows good wearing quality, but the rate of failure was excessively high.

On a 6-degree curve at Mance, there is very little difference in the results between Nickel Chrome and ordinary Open-Hearth, manufactured by the Bethlehem Steel Company. Bessemer rail on same curve shows about double the amount of abrasion in two years, as shown by Nickel Chrome and ordinary Open-Hearth.

GREAT NORTHERN RAILWAY.

An equal number of rails of Manganese rail by Pennsylvania Steel Company, Open-Hearth by the Illinois Steel Company, Algoma Steel Company, Bethlehem Steel Company and Pennsylvania Steel Company, and Bessemer rail by the Algoma Steel Company, Illinois Steel Company and Lackawanna Steel Company, and Ferro Titanium by the Lackawanna Steel Company, were laid on a 5-degree curve one mile east of Hudson, Minn., on the Great Northern Railway.

The Ferro Titanium rail was removed in 23 months on account of being damaged by a wreck.

The Manganese rail is still in track and shows the least wear.

The other rails were removed at the end of 26 months.

The Open-Hearth rail shows the best results, but there is considerable variation in the performance of the rails from the different mills.

LAKE SHORE & MICHIGAN SOUTHERN RAILWAY.

Tests are being made at a number of places of Ferro Titanium, Manganese and electric rails.

In two cases where Ferro Titanium rail was compared with Bessemer rail, the Bessemer rail shows better results than the Ferro Titanium. In one case the reverse is true.

The Manganese 85-lb. rail is compared with Ferro Titanium 100-lb. rail, and the Manganese shows about one-third as much abrasion as the Ferro Titanium rail.

Eighty-pound electric process rail is compared with 100-lb. Bessemer rail and after experience of one to two years, the electric rail shows less abrasion than Bessemer rail. It seems unfortunate that in this case 80-lb. rail is compared with 100-lb. rail.

NORFOLK & WESTERN.

Manganese rail is being compared with Carnegie Bessemer and Bethlehem Open-Hearth.

At 31 months, Manganese rail shows .25 sq. in. abrasion.

At the end of 18½ months, the Carnegie Bessemer rail was removed, showing an abrasion of .82 sq. in.

The Bethlehem Open-Hearth rail, which replaced the Carnegie rail, is still in service and at the end of 12½ months shows .1 sq. in. abrasion.

PENNSYLVANIA LINES WEST.

Northwest System.

Some Open-Hearth special high Silicon rail (Car. .72, Mn. .80, Ph. .029, Sil. .31) is being tested with ordinary Open-Hearth rail.

The rails have been in service but five months and it is too early to draw any conclusions.

The high Silicon rail shows slightly less abrasion than the ordinary Open-Hearth rail.

PENNSYLVANIA LINES WEST.

Southwest System.

A number of kinds of rail has been tested on the Ohio Connecting Railway curve. This test is a comparison between Bessemer, 85-lb., A. S. C. E., Carnegie rail; Bessemer, 85-lb., P. S., Maryland and Cambria rail; Open-Hearth, 85-lb., P. S., Illinois rail, and Mayari (Cuban ore), Open-Hearth, 85-lb., P. S., Pennsylvania Steel Company rail. This rail contains .97 nickel and .21 chromium. After 18 months' service the area abraded was .57 sq. in. The area abraded is as follows:

Carnegie, laid July 1, 1907, three months' service, .672 sq. in.

Carnegie, laid October 9, 1907, 10 months' service, .68 sq. in.

Maryland, laid August 17, 1908, four months' service, .45 sq. in.

Cambria, laid December 24, 1908, seven months' service, .645 sq. in.

Open-Hearth, Illinois, laid August 2, 1909, 11 months' service, .772 sq. in.

WHEELING & LAKE ERIE.

A test of the Ferro Titanium Bessemer, compared with ordinary

Bessemer rail, is being made at two points. There is a little more abrasion on the Ferro Titanium rail than on the ordinary Bessemer rail.

DEDUCTIONS.

(1) The statistics are for all roads and do not take into consideration differences in tonnage and physical characteristics, but are valuable as showing averages derived from studying the performance of large quantities of rail from different mills. The results may be considered as fairly representing the performance of the different mills.

(2) The wide variation in results shown must be due to a great extent to a lack of uniformity in the performance of different mills and also due to a lack of uniformity in the product of any individual mill.

(3) Wide variation from the specified chemistry for rails has been found in the product as furnished by the mills. If a comparatively low carbon has been specified and a higher carbon material has been furnished by the mills than supposed, then erroneous deductions may be drawn unless the chemistry of the rail furnished is accurately determined. There should be greater insistence in the future in seeing that the specified requirements are complied with, and it may be necessary to take chemical tests from the finished product more frequently than heretofore, as well as from the sample test ingots.

(4) The statistics show in many cases that the average performance of the heavier sections is not so good as the average performance of the lighter sections.

(5) The mill people have furnished a long list of defects found in track and track maintenance. It is to be noted that, in many cases, the highest rate of failure of rails is found on roads with a reputation for a high state of maintenance. Head failures, such as split and crushed heads, predominate. The Committee is not willing to admit that such failures are the result of imperfect track conditions.

(6) The Open-Hearth rail, as a whole, shows a lower rate of failure than the Bessemer, but the average rate of failure for Open-Hearth is higher this year than last year, while the Bessemer shows lower rate this year than shown last year. Can it be that, as the age increases, the rate of failure with Open-Hearth rail will increase so as to approach the Bessemer figures?

(7) The statistics indicate that the material in the top of the ingot must be of a poorer quality than that lower down, and that, in many cases, sufficient discard has not been made from the top of the ingot.

As Shown Below RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

Various lb. Various Sec. Various Steel. Rolled by Various Steel Co. Record for Period of One Year ending October 31, 1911.

Lines	Year Laid	Tons of New Rail Laid Even Tons	Specified Chemical Analysis C.	P.	Mn.	Si.	S.		Maximum Axle Load of Locomotives Freight Pounds	Passenger Pounds	Gross Tons over Rail Millions and Tenths	Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1		100 Lb. A.R.A. A Nickel Chrome Bessemer Steel									%																		1
2		Maryland									No.	Norfolk & Western																	2
3	1911	1967	.678	.01	.677	.063	.0528	Avg. Analysis	60000	55000	% No.																—	—	3
4											% No.																		4
5		100 Lb. P.R.R. Sec. Nickel Bessemer Steel									% No.																		5
6		Carnegie									% No.	Pennsylvania Lines East																	6
7	1903 1904	1693	0.51	0.08	0.84	0.11	0.05	Ni. 3.25	58100	62000	% No.	1												1		1	30.0	6.0	7
8											% No.																		8
9		85 Lb. A.S.C.E. Sec. Nickel Bessemer Steel									% No.																		9
10		Carnegie									% No.	Pennsylvania Lines West																	10
11	1903 1907	1655	0.44	0.09	0.80	0.10	0.03	Ni. 3.42	51500	61800	% No.							1						1		1	16.3	6.0	11
12											% No.																		12
13		100 Lb. A.R.A. A Sec. Ferro Titanium Bessemer Steel									% No.																		13
14		Lackawanna									% No.	Central of New Jersey																	14
15	1910	1797	0.50 0.60		0.84 0.10 1.14	0.20			54000	58000	% No.																—	—	15
16		A.R.A. A Sec. Lackawanna	0.50		0.90			P.T.			% No.	Chicago Burlington & Quincy																	16
17	1911	7350	0.60	0.10	1.10			0.3	53320	52700	% No.																—	—	17
18		A.R.A. B Sec. Maryland						Nickel Alloy			% No.	Baltimore & Ohio																	18
19	1910 1911	1986	0.46 0.56	0.10	0.80 1.20	0.05 0.20		0.30 1.00	0.50 1.50	56450	59600	% No.																—	—	19

As Shown Below RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

69

Various lbs Various Sec Various Steel. Rolled by Various Steel Co Record for Period of One Year ending October 31, 1911.

Lines	Year Laid	Tons of New Rail Laid Even Tons	Specified Chemical Analysis C.	P.	Mn.	Si.	S.	Maximum Axle Load of Locomotives Freight Pounds	Passenger Pounds	Gross Tons over Rail Millions and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1											%																		1
2		100 Lb. D&L.W. Sec. Ferro Titanium Bessemer Lackawanna									No.	Delaware Lackawanna & Western																	2
3	1911	86	.16	.092	.61	.108	.051	44250	56670		% No.																		3
4											% No.																		4
5		100 Lb A.R.A.A Sec.-Mayari Bessemer Steel									% No.																		5
6		Maryland									No.	Central of New Jersey																	6
7	1911	2390	0.50 0.60	0.10	0.84 1.14	0.20		54000	58000		% No.																—	—	7
8											% No.																		8
9		100 Lb. A.S.C.E. Sec.-Mayari Bessemer Steel									% No.																		9
10		Maryland									% No.	Boston & Maine																	10
11	1911	1003						45000	48666		% No.																—	—	11
12											% No.																		12
13		100 Lb. N.Y.N.H.&H. Sec.-Mayari Bessemer Steel									% No.																		13
14		Maryland									% No.	New York New Haven & Hartford																	14
15	1911	1028	0.45 0.55	0.10	0.84 1.14	0.20	Cr. 0.50 0.45 Ni. 0.50	47000	53800		% No.								1						1	1	-	9.8	15

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

Various lb. Various Sec. Various Steel. Rolled by Various Steel Co. RAILROAD

Record for Period of One Year ending October 31, 1911.

Lines	Year Laid	Tons of New Rail Laid Even Tons	Specified Chemical Analysis C.	P.	Mn.	Si.	S.		Maximum Axle Load of Locomotives Freight Pounds	Passenger Pounds	Gross Tons over Rail in Millions and Tenths	Kind of Failure
1		100 Lb. A.S.C.E. Sec. Ferro Titanium, Bessemer						%				Broken Tang. / Broken Curve / Flow of Metal Tang. / Flow of Metal Curve / Crushed Head Tang. / Crushed Head Curve / Split Head Tang. / Split Head Curve / Split Web Tang. / Split Web Curve / Broken Base Tang. / Broken Base Curve / Total Tang. / Total Curve / Grand Total
2		Lackawanna						No.				Lake Shore & Michigan Southern
3	1909	136							50000	58400		
4		Dudley Sec. Ferro Titanium Lackawanna-Buffalo						%				Boston & Albany
5	1908 / 1911	23,103	0.45 / 0.70	.096 / 0.10	0.70 / 1.10	0.10 / 0.20	0.06 / 0.75	F.T. 0.02 / 0.03				
6		Lackawanna						%				New York Central & Hudson River
7	1909 / 1910	27,981	0.43 / 0.55	0.10	0.90 / 1.10	0.13 / 0.20	.075	F.T. 0.33	54200	59600		
8								%				
9		90 Lb. A.R.A. "A" Ferro Titanium, Bessemer						%				
10		Lackawanna						%				Atchison Topeka & Santa Fe
11	1911	238	0.54	0.10	1.10	0.20		F.T. 0.3	55200	53500		
12		Lackawanna						%				Chicago, Burlington & Quincy
13	1909 / 1911	13275	0.43 / 0.57	0.10	0.80 / 1.10	0.13 / 0.20		F.T. 0.3	53320	52700		
14		A.R.A. B Sec. Maryland						%				Baltimore & Ohio
15	1910 / 1911	3351	0.45 / 0.55	0.10	0.80 / 1.20	0.05 / 0.20		F.T. 0.15 / 0.30	61600	59600		
16		A.R.A. "B" Sec. Lackawanna						%				Northern Pacific
17	1910 / 1911	6246	0.44 / 0.54	0.10	0.90 / 1.10	0.13 / 0.20		F.T. .375	54730	52300		
18		A.S.C.E. Sec. Lackawanna						%				Central of New Jersey
19	1909	373	0.45 / 0.55	0.10	0.84 / 1.14	0.20		F.T. 0.3	54000	58000		
20		A.S.C.E. Sec. Lackawanna						%				Erie
21	1909 / 1911	4187	0.45 / 0.55	0.10	0.85 / 1.15	0.20	.075	F.T. 0.3	60200	61400		

Lines	Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1																		1
2																		2
3																—	—	3
4																		4
5	1	6						6				5	1	17	18	1.2	7.8	5
6																		6
7	8	3			1	1		4			4	11	13	19	32	-	11.4	7
8																		8
9																		9
10																		10
11	4	1										4	1	5	-	21.8		11
12																		12
13		3			1	1		6	9	8	12	20	8.0	15.0				13
14																		14
15					1	5	7	1			5	9	14	12.5	4.8			15
16																		16
17															17	—		17
18																		18
19		7					2		21				30	30	10.9	8.04		19
20																		20
21	8	1										8	1	9	12.5	2.1		21

As Shown Below RAILROAD

71.

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

Various lb. Various' Sec. Various Steel. Rolled by Various Steel Co. Record for Period of One Year ending October 31, 1911.

Lines	Year Laid	Tons of New Rail Laid Even Tons	Specified Chemical Analysis C.	P.	Mn.	Si.	S.	Maximum Axle Load of Locomotives Freight Pounds	Passenger Pounds	Gross Tons over Rail Hundreds and Tenths	Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1			90 Lb. A.S.C.E. Sec. Con't							%																		1
2			Lackawanna							No.			Lehigh Valley															2
3	1910	10117	0.43 0.53	0.10	0.80 1.10	0.20	FT. 0.05	54000	54000	% No.	3	1				1	2	4	2	1	2	5	9	12	21	1.0	20.7	3
4			A.S.C.E. Sec. Carnegie							% No.			Wheeling & Lake Erie															4
5	1910	1200	0.46 0.56	0.10	0.90 1.10	0.13 0.20	FT. .075 0.3	51200	52200	% No.		5		1		14	1	2					1	22	23	-	192.0	5
6			A.S.C.E. Sec. Lackawanna							% No.			Wheeling & Lake Erie															6
7	1910	1679	0.44 0.54	0.10	0.90 1.10	0.13 0.20	FT. .075 0.3	51200	52200	% No.				73		2								75	75	-	4460	7
8										% No.																		8
9			90 Lb. G.N. Sec. Ferro Titanium Bessemer Steel							% No.																		9
10			Lackawanna							% No.			Great Northern Railway Co.															10
11	1909	2050	0.62 0.75	0.04	0.70 1.10	0.20		54000	58000	% No.						1		3					1	3	4	-	119.5	11
12										% No.																		12
13			85 Lb. A.S.C.E. Sec. Ferro Titanium Bessemer							%																		13
14			Lackawanna							% No.			Atlantic Coast Line															14
15	1910	300	0.48 0.58	0.10	0.80 1.10	0.20	FT. 0.3			% No.	1												1		1	-	33.3	15
16			P.S. Sec. Illinois							% No.			Vandalia															16
17	1911	100	0.45 0.55	0.10	0.80 1.20	0.05 0.20	FT. 0.3	57500	56400	% No.		1										1		2	2	-	200	17
18										% No.																		18
19			80 Lb. A.S.C.E. Sec. Ferro Titanium Bessemer Steel							%																		19
20			Lackawanna							% No.			Munsing Marquette & South-eastern (Lawson & Princeton															20
21										% No.																-	-	21

(Rail Sold Below) RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

Various lb Various Sec. Various Steel. Rolled by Various Steel Co. Record for Period of One Year ending October 31, 1911.

Lines	Year Laid	Tons of New Rail Laid Even Tons	Specified Chemical Analysis C.	P.	Mn.	Si	S.		Maximum Axle Load of Locomotives Freight Pounds	Passenger Pounds	Gross Tons over Rail Millions and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1			80 A.S.C.E Sec. Cont.									%																		1
2			Lackawanna									No.																		2
3	1909	335							44205	44000		%																		3
4			Dudley Sec. Lackawanna									No.	1						1						2		2		- .59	4
5	1910	15279	0.43 0.53	0.10	0.90 1.10	0.13 0.20	.075	0.33	54200	59600		%																		5
6			Dudley Sec. Lackawanna									No.	9	12		2	1		1				9	134	20	148	168	- .110.	6
	1909		043		0.90	0.13		F.T.				%																		
7	1910	31,599	0.53	0.10	1.10	0.20	.075	0.33	54200	59600		No.	26	10					1	1			11	41	38	52	90	- .285	7
8												%																		8
9			101 Lb. DL&W Sec. Ferro Titanium Open Hearth									No.																		9
10			Lackawanna									%																		10
11	1911	287	.785	.021	.975	.148	.045		44250	56670		No.	1												1		1	- .348		11
12			Lackawanna									%																		12
13	1911	1097							44250	56670		No.		1												1	1	- .10		13
14												%																		14
15			100 Lb. A.R.A. B Ferro Titanium Open Hearth									No.																		15
16			Maryland									%																		16
17	1911	229	0.70 0.80	0.10	0.80 1.20	0.65 1.20		F.T. 1.0	56450	59600		No.																		17
18												%																		18
19			110 Lb. L.V. Sec. Ferro Titanium Open Hearth									No.																		19
20			Bethlehem									%																		20
21	1911	7500	0.70 0.83	0.04	0.70 1.00	0.10 0.20		F.T. 0.05	54000	54000		No.		1					2					2		5	5	- .7	21

Various | Various | Various

Baltimore & Ohio

Lehigh Valley

Toledo St. Louis & Western

New York Central & Hudson River

New York Central & Hudson River (Side Lines)

Delaware Lackawanna & Western

Delaware Lackawanna & Western

As Shown Below RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year 73.

Various lb. Various Sec Various Steel. Rolled by Various Steel Co. Record for Period of One Year ending October 31, 1911

Lines	Year Laid	Tons of New Rail Laid Even Tons	Specified Chemical Analysis C.	P.	Mn.	Si.	S.		Maximum Axle Load of Locomotives Freight Pounds	Passenger Pounds	Gross Tons over Rail Including Tender and Trucks		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1		100 Lb. A.R.A.A Ferro Titanium Open Hearth										%																		1
2		Bethlehem										No.			Lehigh Valley															2
3	1911	12700	0.70 0.83	0.04	0.70 0.85	0.10 0.20		F.T. 0.05	54000	54000		%																		3
												No.			1				2						3		3	–	2	
4												%																		4
5		90 Lb. A.S.C.E. Ferro Titanium Open Hearth										No.																		5
6		Bethlehem										%																		6
7	1910	6900	0.70 0.80	0.04	0.80 1.05			F.T. 0.05	54000	54000		No.	10	11	Lehigh Valley				3	3	7	5	5	29	25	48	73	12.	10.57	7
8		Carnegie										%																		8
9	1911	1504	0.70 0.85	0.04	0.70 1.00	0.20						No.			Lehigh Valley						1				1		1	–	7	9
10												%																		10
11		90 Lb. A.R.A.B Sec. Ferro Titanium Open Hearth										No.																		11
12		Maryland										%																		12
13	1911	723	0.65 0.80	0.04	0.75 1.00	0.05 0.20		F.T. 1.0	61600	59600		No.			Baltimore & Ohio															13
14												%																		14
15		101 Lb. D. & L.W. Sec. Chrome Nickel Open Hearth Steel										No.																		15
16		Pennsylvania										%																		16
17	1911	240	.778	.014	.75	.07	.052	N.Cr. 1.12	63600	44250	56670	No.			Delaware Lackawanna & Western													–	–	17
18												%																		18
19		91 Lb. D. & L.W. Sec. Chrome Nickel Open Hearth Steel										No.																		19
20		Bethlehem										%																		20
21	1910	3133	.535	.033	.654	Ni. 2.00	.035	Cr. .541	44250	56670		No.	1	101	Delaware Lackawanna & Western			1	2	3	98			27	5	228	233	–	143	21

Enter under the head of "tons laid" all Kinds of Rail, with names of Manufacturers and Sections, which are in the Main Tracks, whether or not there have been Failures.
Various lb. Various Sec. Various Steel.

As Shown Below RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

74.

Rolled by Various Steel Co.

Record for Period of One Year ending October 31, 1911

Lines	Year Laid	Tons of New Rail Laid Even Tons	Specified Chemical Analysis C.	P.	Mn.	Si.	S.		Maximum Axle Load of Locomotives Freight Pounds	Passenger Pounds	Gross Tons over Rail Joints and Tonnage		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1	90 Lb A.R.A. B Sec Nickel Chrome Open Hearth Steel										%																		1
2	Bethlehem										No.		Baltimore & Ohio																2
3	1909	566	0.50 0.60	0.04	0.70 1.00	0.10 0.20	0.20 0.50	0.50 0.90	56450	59600	%	No.	17	55					23	23	4				40	82	122	795	1215.5	3
4	A.S.C.E Sec. Bethlehem										%																		4
5	1909	5014							54000	58000	No.		175	501	1		4	24	76	185	4		2		256	716	972	1129	1538	5
6											%																		6
7	100 Lb N.Y.N.H.&H. Sec. Mayari Open Hearth Steel										No.																		7
8	Maryland										%		New York New Haven & Hartford																8
9	1911	263	0.59 0.72	0.04	0.60 0.90	0.20	Cr. 0.30 0.45	Ni. about 0.50	47000	53800	No.																	—	—	9

As Shown Below RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

Various lb. Various Sec. Various Steel. Rolled by Various Steel Co. Record for Period of One Year ending October 31, 1911.

Lines	Year Laid	Tons of New Rail Laid Even Tons	Specified Chemical Analysis C.	P.	Mn.	Si.	S.	Maximum Axle Load of Locomotives Freight Pounds	Passenger Pounds	Tons (2000 lbs.) Gross Tons Carried Millions and Tenths	Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1		141 Lb. Girder Sec. Open Hearth Steel																										1
2		Pennsylvania																										2
3	1909 1911	237	0.85	0.12	0.65	0.41		56800	61700																			3
4																												4
5		141 Lb. Girder Sec. Bessemer Steel																										5
6		Pennsylvania																										6
7	1902 1910	2227	0.50	0.08	1.00	0.13		56800	61700																			7
8		Carnegie																										8
9	1902 1906	44	0.50	0.08	1.00	0.13		56800	61700																			9
10																												10
11		85 Lb. Girder Sec. Bessemer Steel																										11
12		Pennsylvania																										12
13	1902 1906	162	0.50	0.08	1.00	0.13		56800	61700																			13
14																												14
15		135 Lb. "Special" Sec. Open Hearth Steel																										15
16		Pennsylvania																										16
17	1910	818	0.90 1.10	0.03	0.60 0.80	0.20		54000	58000								30							30	30	-	36.7	17
18	135 Lb. Spec. Sec.	Passaic Manganese Steel	1.00	0.06	11.0	.250	.020																					18
19	1908	30	1.20	0.11	13.0	.400	.040	61000	47666			1												1	1	-	333.3	19

Pennsylvania Lines East

Pennsylvania Lines East

Pennsylvania Lines East

Central of New Jersey

Delaware & Hudson

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year.

Various lb. Various Sec. Various Steel Rolled by Various Steel Co. Record for Period of One Year ending October 31, 1914.

Lines	Year Laid	Tons of New Rail Laid Even Tons	Specified Chemical Analysis C.	P	Mn.	Si.	S.	Maximum Axle Load of Locomotives Freight Pounds	Passenger Pounds	Gross Tons over Rail Millions and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1	90 Lb. A.R.A. B Sec. Electric Process Steel										%																		1
2	Illinois										No.			Northern Pacific															2
3	1910 1911	279	0.50 & 0.65	0.06	0.50 0.80	0.10 0.18		51730	52300		% No.																—	—	3
4	A.R.A. A Illinois										%			Union Pacific															4
5	1910	916	0.50 0.66	.016 .064	0.52 0.76	.049 .200	.017 .043	56000	48000		% No.																		5
6											% No.																		6
7	80 Lb. A.S.C.E. Sec. Electric Steel										%																		7
8	Illinois										No.			Lake Shore & Michigan Southern Railway															8
9	1910	72						52750	58400		% No.																—	—	9
10	90 Lb. N.Y.N.H.& H Sec. Bessemer Steel										% No.																		10
11	Rerolled from 100 Lb. Rail by American McKenna Process										%			New York New Haven & Hartford															11
12	1909 1911	13418						47000	47000		% No.	31	10			2	2	8	6	5	1			42	23	65	61.5	48.4	12
13											% No.																		13
14	80 Lb. Rerolled Sec. Bessemer Steel										% No.																		14
15	Joliet										%			Pennsylvania Lines East															15
16	1905 1908	3047	0.50	0.08	1.00	0.13		56800	61700		% No.																21	—	16
17	American McKenna Process										% No.			Rock Island Lines															17
18	1906 1911	30605						53000	53550		% No.	8	2					1		1				8	4	12	6.3	3.9	18
19	85 Lb. A.S.C.E. Sec. Manganese Steel										% No.																		19
20	Manganese Steel Rail Co.										%			Atchison Topeka & Santa Fe															20
21	1909 1910	280	1.10 1.20	0.06	11.50 12.00		0.04	58000	56850		% No.		2							2				4	4	—	142.8	21

Summary by Sections, Weights and Kinds of Steel. RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

lb. Sec. Steel. Rolled by Steel Co. Record for Period of One Year ending October 31, 1911.

Lines	Sec.	Tons	Wt.	Kind of Steel	No. of Cos.	Maximum Axle Load of Locomotives: Freight Pounds	Passenger Pounds	Gross Ton Rail Millions and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1	Girder	2,271	141	Bessemer	1	1 Co using 141 lb. Rail			%																—	—	1
									No.																		
2									%																		2
									No.																		
3	ARA[A]	17,879	100	Bessemer	4				%																		3
									No.	10	2	3	2	25	9	52	28	4	3			94	44	138	33	77	
4	ARA[B]	137,904	"	"	5				%																		4
									No.	20	31	12	33	38	48	27	21	13	11	2	7	112	151	263	12.5	19	
5	ASCE	650,932	"	"	14				%																		5
									No.	497	167	24	22	262	141	688	286	65	46	114	70	1650	732	2382	37	37	
6	Dudley	176,284	"	"	2				%																		6
									No.	214	114	2	8	20	38	55	36	11	6	33	10	335	212	547	51	31	
7	N.Y.N. H. & H.	29,822	"	"	1				%																		7
									No.	24	16	3	2	89	21	15	4	12	1	3	2	146	46	192	5	64	
8	P. & R.	8,900	"	"	1				%																		8
									No.	2	1		34	1	4		9	4	1			7	49	56	33	63	
9	P.R.R.	464,825	"	"	2				%																		9
									No.	212	142	3	4	14	12	65	38	176	90	25	10	495	296	791	19	17	
10	P.S.	100,856	"	"	2				%																		10
									No.	19	11	1	23	19	25	50	54	24	15	3		116	128	244	16	24	
11	Total	587,402	"	"	—	23 Cos. using 100 lb. Rail			%																		11
									No.	998	484	48	128	468	298	952	476	309	173	180	99	2955	1658	4613	30	29	
12									%																		12
									No.																		
13	B. & A.	61,678	95	Bessemer	1	1 Co. Using 95 lb. Rail			%																		13
									No.	13	19		1	3	17	17	49	5	2	1		39	88	127	33	21	
14									%																		14
									No.																		
15	ARA[A]	92,891	90	Bessemer	5				%																		15
									No.	58	4	1	3	24	10	44	21	8	2	3	1	138	41	179	17.3	19	
16	ARA[B]	140,746	"	"	4				%																		16
									No.	35	49	4	30	208	314	199	274	16	32	2	4	464	703	1167	92.	82	
17	ASCE	911,106	"	"	15				%																		17
									No.	768	346	340	258	454	281	695	311	185	87	361	159	2803	1442	4245	61.5	47	
18	C.S.	115,020	"	"	6				%																		18
									No.	95	24	12	6	61	39	252	172	17	10	19	4	456	255	711	67.5	62	
19	G.N.	40,776	"	"	1				%																		19
									No.	35	9	2	18	12	48	28	34	8	8	150	22	235	139	374	21.5	92.	
20	Peculiar	13,418	"	"	1				%																		20
									No.	31	10			2	2	8	6		5	1		42	23	65	61.5	484	
21	Total	2,312,040	"	"		28 Cos. using 90 lb. Rail			%																		21
									No.	1022	442	359	315	761	694	1226	815	234	144	536	190	4138	2603	6741	61	51	

Summary by Sections, Weights and Kinds of Steel RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

lb. Sec. Steel. Rolled by Steel Co. Record for Period of One Year ending October 31, 1911.

Lines	Sec.	Tons	wt.	Kind of Steel	No. of Co's.	Maximum Axle Load of Locomotives: Freight Pounds	Maximum Axle Load of Locomotives: Passenger Pounds	Gross Tons over Rail Millions and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Failures per 10,000 Tons of New Rail Laid: Present Year	Lines
1	ARA[A]	3916	85	Bessemer	1				%																		1
									No.		1			2		1		2	2			5	3	8	112	20	
2	ASCE	2,599,295	"	"	25				%																		2
									No.	1869	823	98	230	1056	715	1745	692	358	130	844	275	5970	2865	8835	355	34.	
3	GB&Q	208,995	"	"	1				%																		3
									No.	71	42	6	26	33	37	379	155	4	4	71	40	564	304	868	58	42	
4	C.P.	44,285	"	"	1				%																		4
									No.	74	49	3	16	1	2	18	29	2	5	18	10	116	111	227	-	5.0	
5	Girder	162	"	"	1				%																		5
									No.																-	-	
6	Mo.P.	123,307	"	"	2				%																		6
									No.	40	42			71	64	67	46	6	7	3	1	187	160	347	6	27	
7	O.R&N.	4,352	"	"	1				%																		7
									No.	6												6		6	-	14	
8	P.RR	615,583	"	"	6				%																		8
									No.	147	134	16	14	98	40	263	139	86	62	91	68	701	457	1158	17.5	18.5	
9	P.S.	121,860	"	"	5				%																		9
									No.	41	16	1	10	70	38	87	51	53	17	4	1	256	133	389	29.5	32	
10	Total	3721,755	"	"		33 Cos using 85 lb. Rail			%																		10
									No.	2248	1107	124	296	1331	896	2560	1112	511	227	1031	395	7805	4033	11838	33	32	
11									%																		11
									No.																		
12	ARA[A]	5212	80	Bessemer	2				%																		12
									No.																-	-	
13	ASCE	1,909,933	"	"	40				%																		13
									No.	556	266	123	109	600	335	1227	434	181	88	155	74	2842	1306	4148	26.5	21.	
14	C.S.	4,000	"	"	1				%																		14
									No.																-	-	
15	Cambria 540	6,141	"	"	1				%																		15
									No.	4				12		4	1					20	1	21	-	34	
16	Dudley	255,249	"	"	3				%																		16
									No.	54	48	19	12	19	18	70	43	12	2	12	29	186	152	338	16.5	13	
17	Roanoke	33,652	"	"	2				%																		17
									No.	8	2						1		1			8	4	12	-	3.5	
18	Total	2214187	"	"		43 Cos using 80 lb. Rail			%																		18
									No.	622	316	142	121	631	353	1301	479	193	91	167	103	3056	1463	4519	25	20.	
19	NY NH&H	16,824	78	Bessemer	1	1 Co using 78 lb. Rail			%																		19
									No.	4	6				1	2		1		1		8	7	15	8.3	9.	
20									%																		20
									No.																		
21	B&M	448	76	Bessemer	1	1 Co using 76 lb. Rail			%																		21
									No.		2												2	2	-	45	

Summary by Sections, Weights and Kinds of Steel RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

lb. Sec. Steel. Rolled by Steel Co. Record for Period of One Year ending October 31, 191

Lines	Sec.	Tons	Wt.	Kind of Steel	No. of Cos.	Maximum Axle Load of Locomotives: Freight Pounds	Maximum Axle Load of Locomotives: Passenger Pounds	Gross Tons over Rail Millions and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Failures per 10,000 Tons of New Rail Laid: Present Year	Lines
1	ASCE	353,419	75	Bessemer	9				%																		1
									No.	84	43	10	23	40	31	64	54	22	18	1	2	221	171	392	21	11.	
2	B&M.	176,778	"	"	2				%																		2
									No.	257	183	5	10	53	161	88	110	23	16	64	73	490	553	1043	133	58.	
3	C.S.	312,487	"	"	7				%																		3
									No.	145	66	45	26	163	102	433	222	92	378	39	11	917	805	1722	44.	55.	
4	Mo.P.	75,570	"	"	1				%																		4
									No.	9	2	1	1	3	2	2	4	2			1	17	10	27	3	3.5	
5	O.R.&N.	8,709	"	"	1				%																		5
									No.	3	4		1			2				1		6	5	11	—	13.	
6	P.R.R.	1,566	"	"	1				%																		6
									No.																13.	—	
7	Total	928,529	"	"	—	19 Cos using 75 lb. Rail			%																		7
									No.	498	298	61	61	259	296	589	390	139	412	105	87	1651	1544	3195	26	34.	
8									%																		8
									No.																		
9	C.&N.W.	241,655	72	Bessemer	2	2 Cos using 75 lb. Rail			%																		9
									No.	60	26	4	2	47	0	52	14	7	2	3		174	50	224	9.5	83.	

Summary by Sections Weights & Kind of Steel RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

Various lb. Various Sec. Various Alloys Steel. Rolled by _____ Steel Co. Record for Period of One Year ending October 31, 1911.

Lines	Sec.	Tons	Wt.	Alloy	Kind of Steel	No. of Rails	Passenger Pounds	Gross Tons over Rail Millions and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1	PRR	1693	100	Nickel	Bessemer	1			%																		1
									No.	1												1		1	30.	6.	
2	ASCE	1655	85	"	"	1			%																		2
									No.							1						1		1	163	6.	
3	Total	3348		"	"	2			%																		3
									No.	1						1						2		2	96.	6.	
4									%																		4
									No.																		
5	ARA[A]	1967	100	Nickel Chromium	Bessemer	1			%																		5
									No.																—	—	
6									%																		6
									No.																		
7	ARA[A]	2390	100	Maysari	Bessemer	1			%																		7
									No.																—	—	
8	ASCE	1003	"	"	"	1			%																		8
									No.																—	—	
9	N.Y.N. Hav.Sec	1022	"	"	"	1			%							1							1	1			9
									No.																—	10	
10	Total	4415	"	"	"	3			%							1							1	1			10
									No.																—	2	
11	ARA[A]	9147	100	Ferro Titanium	Bessemer	2			%																		11
									No.																—	—	
12	ARA[B]	1986	"	"	"	1			%																		12
									No.																—	—	
13	ASCE	136	"	"	"	1			%																		13
									No.		1					1							2	2	—	147	
14	Dudley	51084	"	"	"	1			%																		14
									No.	9	9			1	1		10			4	16	14	36	50	1.1	10.	
15	D&LW	86	"	"	"	1			%																		15
									No.																—	—	
16	Total	62439	"	"	"	—			%																		16
									No.	9	10			1	1		11			4	16	14	38	52	1.3	8.3	
17	ARA[A]	13513	90	Ferro Titanium	Bessemer	2			%																		17
									No.	4	4					1		1		6	9	12	13	25	8.	18.5	
18	ARA[B]	9597	"	"	"	2			%																		18
									No.							5	7		1			5	9	14	5.	15	
19	ASCE	17556	"	"	"	4			%																		19
									No.	11	14		74		17	3	6	2	3	2	26	18	140	158	48	89	
20	GN.	2050	"	"	"	1			%																		20
									No.					1			3					1	3	4	—	20.	
21	Total	42716	"	"	"				%																		21
									No.	15	18		74	1	17	9	16	3	4	8	35	36	164	196	22	45	

Summary by Sections Weights & Kind of Steel RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

81.

Various th Various Sec Various Steel. Rolled by Steel Co. Record for Period of One Year ending October 31, 1911.

Lines	Sec.	Tons	Wt.	Alloy	Kind of Steel	No. of Cos.	Passenger Pounds	Gross Tons over Rail Millions and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Failures per 10,000 Tons of New Rail Laid: Present Year	Lines
1	ASCE	300	85	Ferro Titanium	Bessemer	1			%																–	33.	1
									No.	1												1		1			
2	P.S.	100	"	"	"	1			%											1			2	2	–	200	2
									No.	1	1									1			2				
3	Total	400	"	"	"				%																–	75	3
									No.	1	1									1		1	2	3			
4									%																		4
									No.																		
5	ASCE	397	80	Ferro Titanium	Bessemer	2			%																–	–	5
									No.																		
6	Dudley	46878	"	"	"	1			%																–	55	6
									No.	35	22			2	1	1	2			20	175	58	200	258			
7	Total	47275	"	"	"				%																–	54.5	7
									No.	35	22			2	1	1	2			20	175	58	200	258			
8		–							%																		8
									No.																		
9	Sec.	Tons	Wt.	Kind of Steel		No. of Co's.			%	Summary All Sections & Weights, Bessemer Steel																	9
10	All	2,271	141	Bessemer		1			No.																		10
	"	1,587,402	100	"		23			No.	998	484	48	128	468	298	952	476	309	173	180	99	2955	1658	4613	30.	29.	
11	"	61,678	95	"		1			%																		11
									No.	13	19		1	3	17	17	49	5	2	1		39	88	127	33.	21.	
12	"	1,313,957	90	"		28			%																		12
									No.	1022	442	359	315	761	694	1226	818	234	144	536	190	4138	2603	6741	61.	51.	
13	"	3,721,755	85	"		33			%																		13
									No.	2248	1107	124	296	1331	896	2560	1112	511	227	1031	395	7805	4033	11838	33.	32	
14	"	2,214,187	80	"		43			%																		14
									No.	622	316	142	121	631	353	1301	479	193	91	167	103	3056	1463	4519	25.	20.	
15	"	16,824	78	"		1			%																		15
									No.	4	6				1	2		1		1		8	7	15	8.3	9.	
16	"	448	76	"		1			%																		16
									No.		2												2	2	–	45.	
17	"	928,529	75	"		19			%																		17
									No.	498	298	61	61	259	296	589	390	139	412	105	87	1651	1544	3195	26.	34.	
18	"	241,655	72	"		2			%																		18
									No.	60	26	4	2	47	6	53	14	7	2	3		174	50	224	9.5	83.	
19	All	10088,706					81 Co's using Bessemer Rail		%																		19
									No.	5465	2700	738	924	3500	2561	6700	3338	1399	1051	2024	874	19826	11448	31274	33	31	

Summary by Sections Weights & Kinds of Steel — RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

lb. Sec Steel. Rolled by Steel Co. Record for Period of One Year ending October 31, 1911.

Lines	Sec.	Tons	Wt.	Alloy	Kind of Steel	No. of Cos.	Passenger Pounds	Gross Tons over Rail Millions and Tenths	Kind of Failure														Grand Total	Failures per 10,000 Tons of New Rail Laid		Lines
									Broken		Flow of Metal		Crushed Head		Split Head		Split Web		Broken Base		Total			Last Year	Present Year	
									Tang.	Curve	Tang.	Curve	Tang.	Curve	Tang.	Curve	Tang.	Curve	Tang.	Curve	Tang.	Curve				
1									% / No.	Summary All Sections Weights & Kinds of Alloys Bessemer																1
2	All	3348	All	Nickel	Bessemer	2			%						1						2		2	96	6.	2
									No.	1					1						2					
3	"	1967	"	Nickel Chromium	"	1			% / No.															—	—	3
4	"	4415	"	Mayari	"	3			%							1					1		1	—	2	4
									No.							1					1					
5	"	152830	"	Ferro Titanium	"	24			%	60	51	74	4	19	10	29	3	4	32	227	109	404	513	13.5	33.5	5
									No.	60	51	74	4	19	10	29	3	4	32	227	109	404	513			
6	Total	162,560	"	All Alloys	"		20 Cos using Bess. Alloys		%	61	51	74	4	19	11	30	3	4	32	227	111	405	516	19.	31.7	6
									No.	61	51	74	4	19	11	30	3	4	32	227	111	405	516			
7									% / No.																	7
8									% / No.	Summary Various Sections Various Kinds of Steel																8
9	A.R.A.A	916	90		Electric Process	1			%															—	—	9
									No.																	
10	A.R.A.B	279			"	1			%															—	—	10
									No.																	
11	A.S.C.E.	72	85		"	1			%															—	—	11
									No.																	
12	Total	1267	—		"		3 Cos. using		%																	12
									No.																	
13	Special	30	135		Manganese	1	1 Co Using		%		1										1		1	—	333.3	13
									No.		1										1					
14	A.S.C.E.	280	85		Manganese	1	1 Co. Using		%		2						2				4		4	—	107.1	14
									No.		2						2				4					
15	Total	310	—		"	2	2 Co. Using		%		3						2				5		5	—	96.2	15
									No.		3						2				5					

Summary by Sections, Weights & Kinds of Steel — RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

lb. Sec. Steel. Rolled by Steel Co. Record for Period of One Year ending October 31, 1911

Lines	Sec.	Tons	Wt.	Kind of Steel	No. of Co's	Max. Axle Load of Locomotives: Freight Pounds	Max. Axle Load of Locomotives: Passenger Pounds	Gross Tons over Rail Millions and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Failures per 10,000 Tons of New Rail Laid: Present Year	Lines
1	Girder	237	141	Open Hearth	1	1 Co. using			%																—	—	1
									No.																		
2	Special	818	135	" "	1	1 Co. using			%																—	366.7	2
									No.								30						30	30			
3	ARA[a]	39488	100	Open Hearth	4				%																16.	22.	3
									No.	11	24	1		1	1	29	11	1	6	1		44	42	86			
4	ARA[b]	52410	"	"	4				%																1.	9.	4
									No.	6	7		15	1	9	4	5			1		12	36	48			
5	ASCE	188021	"	"	6				%																9.	9.	5
									No.	51	25			7		35	20	10	5	17	3	120	53	173			
6	Dudley	11517	"	"	2				%																11+	—	6
									No.																		
7	D&LH	12770	"	"	1				%																—	—	7
									No.																		
8	N.Y. NH&H	30553	"	"	1				%																21+	31	8
									No.	13	3			1	1	7	2	51	14	1	1	73	21	94			
9	PRR	1107	"	"	1				%																55	54.	9
									No.		1				2	2		1				3	3	6			
10	P.S.	122229	"	"	3				%																14	12.	10
									No.	11	27	8	10	11	22	9	25	10	18		1	49	103	152			
11	P&R	19000	"	"	1				%																6.5	16.	11
									No.	2			21		3		3		1			2	28	30			
12	Total	477095	"	"		21 Cos using 100 lb. Rail			%																10.5	12.	12
									No.	94	87	9	46	21	38	86	66	73	44	20	5	303	286	589			
13									%																		13
									No.																		
14	ARA[a]	305264	90	Open Hearth	12				%																10.	9.	14
									No.	21	18	9	12	15	11	66	62	21	16	10	11	142	130	272			
15	ARA[b]	154867	"	"	4				%																18.	25	15
									No.	41	143	2	7	21	58	23	45	23	12	5	12	115	277	392			
16	ASCE	96823	"	"	8				%																72.5	51	16
									No.	103	149	14	15	10	32	32	43	24	31	8	28	191	298	489			
17	C.S.	147987	"	"	6				%																16.3	9.	17
									No.	27	9	1	10	10	26	13	28	3	3	5	3	59	79	138			
18	D.L.W.	65959	"	"	1				%																16.3	22	18
									No.	35	76	1		2	5	6	10	4	2	1	3	49	96	145			
19	C.N.	88428	"	"	1				%																8.	53	19
									No.	180	24	4	2	21	15	69	67	8	4	71	6	353	118	471			
20	S.Fe.	148224	"	"	1				%																4.	5.	20
									No.	7	1	1	1	9	16	10	2	16	4	2		45	24	69			
	T[illegible]	[illegible]552	"	"		27 Cos using 90 lb. Rail			%																19.	20.	21
									No.	414	420	32	47	88	163	219	257	99	72	102	63	954	1022	1976			

Summary by Sections Weights & Kinds of Steel

RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

lb. Sec. Steel. Rolled by Steel Co. Record for Period of One Year ending October 31, 1941

Lines	Year Laid / Sec.	Tons	Wt.	Kind of Steel	No. of Co's.	Maximum Axle Load of Locomotives: Freight Pounds	Passenger Pounds	Gross Tons over Rail Wheels and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
1	ARA A	22841	85	Open Hearth	1				%																		1
									No.	3				11	7	10	1	2	3	1		27	11	38	14.8	17.	
2	ASCE	419141	"	"	15				%																		2
									No.	44	37	5	5	26	54	16	30	24	13	3	6	118	145	263	10.	6.	
3	C.P.R.	45995	"	"	1				%																		3
									No.	51	43	11	21	2	10	39	112	5	11	50	35	158	232	390	-	84.	
4	C.B.&Q.	10000	"	"	1				%																		4
									No.					1		14	2			2		17	2	19	30.	19	
5	No.P.	8946	"	"	1				%																		5
									No.	2						2						4		4	22.	5	
6	P.S.	62684	"	"	4				%																		6
									No.	4	8	2	6	10	8	7	13	5	17			28	52	80	14.	13	
7	Total	569607	"	"		21 Cos using 85 lb. Rail			%																		7
									No.	104	88	18	32	50	79	88	158	36	44	56	41	352	442	794	11.3	14	
8									%																		8
									No.																		
9	ASCE N.Y.	426317	80	Open Hearth	11				%																		9
									No.	329	194	50	88	121	105	207	158	81	54	392	100	1180	699	1879	27.3	44.	
10	NH&H.	18642	"	"	1				%																		10
									No.		6							3	3	2		5	9	14	-	8.	
11	Total	444959	"	"		12 Cos using 80 lb Rail			%																		11
									No.	329	200	50	88	121	105	207	158	84	57	394	100	1185	708	1893	27.3	42.	
12									%																		12
									No.																		
13	ASCE	60506	75	Open Hearth	3				%																		13
									No.	17	8					1		4	2	15	4	37	14	51	13.	84	
14	B&M.	11135	"	"	1				%																		14
									No.	17	6									1	5	18	11	29	-	26	
15	C.S.	28099	"	"	3				%																		15
									No.	1	1					2	1					3	2	5	2.8	2.	
16	Total	99740	"	"		7 Cos using 75 lb. Rail			%																		16
									No.	35	15					3	1	4	2	16	9	58	27	85	9.3	9.	

Summary by Sections Weights and Kind of Steel RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

Various lb. Various Sec. Various Alloys Steel. Rolled by _____ Steel Co. Record for Period of One Year ending October 31, 191/.

Lines	Sec.	Tons	Wt.	Alloy	Kind of Steel	No. of Sec.	Gross Tons over Rail Millions and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Failures per 10,000 Tons of New Rail Laid: Present Year	Lines
1	DL&W	240	101	Nickel	Open Hearth	1		%																—	—	1
								No.																		
2	"	3133	91	Nickel Chromium	Open Hearth	1		%																—	743	2
								No.	1	101			1	2	3	98				27	5	228	233			
3	ARA.B	566	90	"	"	1		%																795	2156	3
								No.	17	55					23	23		4			40	82	122			
4	ASCE	5014	"	"	"	1		%																1129	1938	4
								No.	175	501	1		4	24	76	185		4		2	256	716	972			
5	Total	8713	—	"	"			%																—	1523.	5
								No.	193	657	1		5	26	102	306		8		29	301	1026	1327			
6								%																		6
								No.																		
7	W.Y.N. W.&H.	263	100	Mayari	Open Hearth	1		%																—	—	7
								No.																		
8								%																		8
								No.																		
9	L.V.	7500	110	Ferro Titanium	Open Hearth	1		%																—	7	9
								No.		1						2				2		5	5			
10								%																		10
								No.																		
11	D&L.W.	1384	101	Ferro Titanium	Open Hearth	1		%																—	14.	11
								No.	1	1											1	1	2			
12								%																		12
								No.																		
13	ARA.B	12700	100	Ferro Titanium	Open Hearth	1		%																—	2	13
								No.			1				2						3		3			
14	ARA.B	229	"	"	"	1		%																—	—	14
								No.																		
15	Total	12929	"	"	"	2		%																—	2.	15
								No.			1				2						3		3			
16								%																		16
								No.																		
17	ARA.B	723	90	Ferro Titanium	Open Hearth	1		%																		17
								No.																		
18	ASCE	8404	"	"	"	1		%																—	88.	18
								No.	10	11					3	3	8	5	5	29	26	48	74			
19	Total	9127	"	"	"	2		%																—	81.	19
								No.	10	11					3	3	8	5	5	29	26	48	74			

Summary by Sections, Weights & Kind of Steel

RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

lb. Sec. Steel. Rolled by Steel Co. Record for Period of One Year ending October 31, 1911.

Sec.	Tons	Wt.	Kind of Steel		No. of Cos		Gross Tons over Rail without Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Present Year	Lines
								%	Summary all Sections & Weights Open Hearth Steel.																	1
All	237	141	Open Hearth		1			No.																—	—	2
"	818	135	"	"	1			%								30						30	30	—	366.7	3
"	477,095	100	"	"	21			No.	94	87	9	46	21	38	86	66	73	44	20	5	303	286	589	10.5	12	4
"	1,007,552	90	"	"	27			%																		5
"	569,607	85	"	"	21			No.	414	420	32	47	88	163	219	257	99	72	102	63	954	1022	1976	19	20.	6
"	444,959	80	"	"	12			%																		7
"	99,740	75	"	"	7			No.	329	200	50	88	121	105	207	158	84	57	394	100	1185	708	1893	27.3	42.	8
								%																		
Total	2600,008	All	"	"		54 Cos using Open Hearth		No.	976	810	109	213	280	385	603	670	296	219	588	218	2852	2516	5367	11.5	20	9
								%																		
								No.																		10
Sec.	Tons	Wt	Alloy	Kind of Steel				%	Summary all Sections Weights & Kinds of Alloys Open Hearth																	11
All	240	All	Nickel	Open Hearth	1			No.																		12
"	8713	"	Nickel Chromium	"	3			%																		
								No.	193	657	1		5	26	102	306		8		29	301	1026	1327	—	1523	13
"	263	"	Mayari	"	1			%																		
								No.														1		—	—	14
"	30940	"	Ferro Titanium	"	3			%																		
								No.	11	13	1				5	5	8	5	5	31	30	54	84	12.	27.	15
								%																		
All	40156	"	All	"		5 Cos using Open Hearth Alloys		No.	204	670	2		5	26	107	311	8	13	5	60	331	1080	1411	—	351	16

General Summary by Sections Weights & Kinds of Steel RAILROAD

Summary of Steel Rail Failures for One Year Compared with same Period of Previous Year

87.

_____ lb. _____ Sec. _____ Steel. Rolled by _____ Steel Co. Record for Period of One Year ending October 31, 1911.

Lines	Sec.	Tons	wt.	Kind of Steel	No. of Co's	Maximum Axle Load of Locomotives: Freight Pounds	Maximum Axle Load of Locomotives: Passenger Pounds	Gross Tons of Rail Without and Tenths		Kind of Failure: Broken Tang.	Broken Curve	Flow of Metal Tang.	Flow of Metal Curve	Crushed Head Tang.	Crushed Head Curve	Split Head Tang.	Split Head Curve	Split Web Tang.	Split Web Curve	Broken Base Tang.	Broken Base Curve	Total Tang.	Total Curve	Grand Total	Failures per 10,000 Tons of New Rail Laid: Last Year	Failures per 10,000 Tons of New Rail Laid: Present Year	Lines
1	All	10,088,706	All	Bessemer	81				%																		1
									No.	5465	2700	738	924	3500	2561	6700	3338	1399	1051	2024	874	19826	11448	31274	33	31.	
2	"	2,600,008	"	Open Hearth	55				%																		2
									No.	976	810	109	213	280	385	603	670	296	219	588	218	2852	2515	5367	11.5	20.	
3	"	162,560	"	Alloys-Bess'r.	20				%																		3
									No.	61	51		74	4	19	11	30	3	4	32	227	111	405	516	115	32.	
4	"	40,156	"	" O.H.	5				%																		4
									No.	204	670	2		5	26	107	311	8	13	5	60	331	1080	1411	89	351	
5	"	1,267	"	Electric Process	3				%																		5
									No.																—	—	
6	"	310	"	Manganese	2				%																		6
									No.		3								2				5	5	—	107	
7	Total	12893087	All	All					%																		7
									No.	6706	4234	849	1211	3789	2991	7421	4349	1706	1289	2649	1379	23120	15453	38573	31	30	
8				Excluding Alloys-Bessemer Open Hearth & Electric Manganese																						30.6	28.8	8
9				Alloys-Bessemer & Open Hearth																						111.2	95.1	9

Baltimore & Ohio RAILROAD

Record of Comparative Wear of Special Rail

Tests Completed in Past Year

Date of Report October 31st 1941

Special Rail: Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition: C	P	Mn	Si	S	Chemical Composition of Rail of Section with which Special Rail was Compared: C	P	Mn	Si	S	Special and Comparative Rails: Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken: Special Sq. in. abraded	Special % of Area of Head	Comparative Sq. in. abraded	Comparative % of Area of Head
	Glencoe, Pa.					.45		.85	.10										H=779	23.4		
Bessemer	Conn. Div. 7°Curve E.B.M.	4.43	90	R.A	Illinois Steel Co.	.55	*.10	1.15	.20	*.075						12/08	1/11	2Y.1Mo.	L=661		H=550 L=303	19.4
											Carnegie 90 lb. R.B. Bessemer											
											.45		.85									
											.55	*.10	1.15	.075								
	Williams, Pa.					.65		.75	.10													
Open Hearth	Conn. Div. 6°Curve E.B.M.	35.4	90	R.B.	Bethlehem	.75	*.06	1.00	.20							10/08	12/11	3Y2M	H=813 L=631	20.8		
										Ti Alloy												
	Kessler's Curve					.45		.80	.05	%												
Titanium	Cumb. Div. 9°Curve E.B.M.	3.98	90	R.B.	Maryland	.55	*.10	1.20	.20	0.3						8/10	12/11	1Y.4Mo.	*0.491	14.40		
		"	"	"	"	"	"	"	"	0.5									*0.450	13.18		
		"	"	"	"	"	"	"	"	1.0									*0.510	15.00		
		"	"	"	"	"	"	"	"	1.5									*0.453	13.29		
											Maryland 90 lb. Open Hearth											
											.65	.013	.75	1.12	.028						*0.587	17.18

* Based on an annual rate of abrasion so as to include all rails removed prior to the close of the Test

* Not to exceed

Baltimore & Ohio RAILROAD 178.

Record of Comparative Wear of Special Rail

Tests Completed in Past Year.

Date of Report October 31st 1911

Special Rail: Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Special Rail: Chemical Composition C	P	Mn	Si	S	Nic	Chr	Chemical Composition of Rail of Section with which Special Rail was Compared: C	P	Mn	Si	S	Special and Comparative Rails: Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken: Special Sq. In. abraded	Special % of area of Head	Comparative Sq. In. abraded	Comparative % of area of Head
						.50		.70	.05		2.0	.50										H=6.38 L.416	15.1%		
Nickel Chrome	Bloomington Cumberland Div. 70.37 E.B.M.	7.08	90	R.B.	Bethlehem	.60	*0.10	1.20	.20		2.5	.90						4/09	12/11	2Y.8M.				
													Bethlehem Ordinary Open Hearth											
													.65		.75	.05							H=.867 L=.683	22.4%
													.80	*.04	1.00	.20								
Nickel Chrome	Mance, Pa. Connellsville Div. 8° E.B.M.	7.96	90	R.B.	Bethlehem	"	"	"	"		"	"						4/09	12/11	2Y.8Mo.	H=.408 L=.382	11.2%		
													Bethlehem Ordinary Open Hearth											
													.65		.75	.05		4/09	12/11	2Y.8M.			H=.603 L=.550	16.4%
													.80	*.04	1.00	.20								
													Cambria Bessemer											
													.45		.80	.05		4/09	4/11	2Y.			H=.945 L=.555	23.5
													.55	*.10	1.20	.20								
Nickel Chrome	Mance, Pa. Connellsville Div. 6° E.B.M.	8.04	90	R.B.	Bethlehem	"	"	"	"		"	"						4/09	12/11	2Y.8M.	H=.432 L=.274	10.0%		
													Bethlehem Ordinary Open Hearth					4/09	4/11	2Y.			H=.390 L=.395	11.0
													.65		.75	.05								
													.80	*.04	1.00	.20								
													Cambria Bessemer											
													.45		.80	.05		4/09	4/11	2Y.			H=.783 L=.613	20.0
													.55	*.10	1.20	.20								

*Not to exceed % Based on an annual rate of abrasion so as to include all rails removed prior to the close of the test.

GREAT NORTHERN RAILWAY COMPANY RAILROAD

Record of Comparative Wear of Special Rail

Date of Report NOVEMBER 1ST 1911

Special Rail																Chemical Composition of ... Rail of ... Section with which Special Rail was Compared						Special and Comparative Rails							
Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition																Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken				
						C	P	Mn	Si	S						C	P	Mn	Si	S					Special		Comparative		
																									Sq. In. abraded	% of area of Head	Sq. In. abraded	% of area of Head	
Manganese	HUSON, MINN	5	90Lb	G.N.	PENN. ST. CO.	1.25	—	10-13	—													Aug 1909	Not Removed	26 Mo.	.25	7.79			
Open Hearth	"	"	"	"	ILL. ST. CO.	62-75	.04	70-100	.20													"	Dec. 1911	"	.42	12.88			
" "	"	"	"	"	ALGOMA ST. CO.	—	—	—	—													"	"	"	.49	15.12			
" "	"	"	"	"	BETHLEHEM S.CO.	65-80	.04	60-90	.20													"	"	"	.57	17.74			
" "	"	"	"	"	PENN. ST. CO.	59-72	.04	60-90	.20													"	"	"	.62	19.21			
BESSEMER	"	"	"	"	ALGOMA ST. CO.	—	—	—	—													"	"	"	.79	24.38			
"	"	"	"	"	ILL. ST. CO.	43-53	.10	80-110	.20													"	"	"	.84	26.62			
"	"	"	"	"	LACK ST. CO.	45-55	.04	84-114	.20													"	"	"	1.19	36.72			
BESS. FERRO-TITANIUM	"	"	"	"	" " "	62-75	.04	70-100	.20							REMOVED 1/4 DAMAGED BY WRECK						"	SEPT 11	23 Mo.	.65	20.06			

The above Rails were placed in 5 Degree Curve one Mile East of Huson, Minn. For purpose of ascertaining Comparative Wearing Qualities of each Kind of Rail under the heavy ore traffic in that territory. During the time these rails were in track they were subjected to the movement of Forty million Gross Tons.

THE LAKE SHORE & MICHIGAN SOUTHERN RY. RAILROAD 182

Record of Comparative Wear of Special Rail

Date of Report MAY 13, 1912

Special Rail: Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Special Rail: Chemical Composition C	P	Mn	Si	S			Chemical Composition of Bessemer Rail of A.S.C.E. Section with which Special Rail was Compared: C	P	Mn	Si	S			Special and Comparative Rails: Date Laid	Date Removed	Length of Service* at date of Report	Average Area Abraded of all the Sections taken: Special Sq. In. abraded	Special % of area of Head	Comparative Sq. In. abraded	Comparative % of area of Head	How Laid or Life of Rail Replaced
Ferrotitanium	1/2 M.W - Buffalo	1	100#	A.S.C.E.	Lackawanna S. Co.								.45 to .55	Not over .10	.90 to 1.10	Not over .20				9/09	8/11	1 Yr. 11 Mo.	1.07	23.4	0.70	16.9	1 Yr. 1 Mo.
Do	1 1/2 M.W. "	11	"	"	"								do	do	do	do				6/09	In Track	2 Yr. 8 Mo.	0.64	16.6	0.61	14.0	Alternate
Do	1 M.W - Dunkirk	33	"	"	"								do	do	do	do				6/09	No Report						
Do	Willoughby Curve	37	"	"	"															9/09	No Report						
Do	1 3/4 M.E. Chicago	14	"	"	"															9/09	10/11	2 Yr.	0.60	14.5	0.50	12.5	2 Years
	Total	96	"	"	"																						
	Compr. Trks.																										
Manganese	3/4 M.W - Buffalo	4	85#	P.R.R.	Penna. St. Co.								Compared with Ferrotitanium 100# A.S.C.E.							4/10	In Trk.	1 Yr. 10 Mo.	0.30	8.7	1.07	23.4	1 Yr. 11 Mo.
	Total	4	"	"	"																						
Electric	1 M.W - Irving	11	80#	A.S.C.E.	Illinois S. Co.															3/10	No Report						
Do	Wm. Street, E. Buffalo	11	"	"	"															4/10	In Trk.	1 Yr. 11 Mo.	0.30	9.2	0.56	17.0	Alternate
Do	Ashtabula	12	"	"	"								Compared with Bessemer 100# A.S.C.E.							3/10	"	1 Yr. 11 Mo.	0.36	11.4	0.55	13.3	Alternate
Do	Collinwood Yard	22	"	"	"															3/10	No Report						
Do	Wick, O	389	"	"	"															4/10	In Track	2 Yr.	0.06	1.8	0.06	1.8	Alternate
Do	Springfield	28	"	"	"															3/10	No Report						
Do	West Seneca	9	"	"	"															4/10	In Track	1 Yr. 10 Mo.	0.56	17.1	0.83	25.4	Alternate
	Total	471	"	"																							

NORFOLK & WESTERN RAILWAY COMPANY — RAILROAD

Record of Comparative Wear of Special Rail

Date of Report OCT. 31 ST 1911.

Special Rail																		Special and Comparative Rails								
Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition							Chemical Composition of Carnegie Bessemer & Bethlehem Open Hearth Rail of A.S.C.E. Section with which Special Rail was Compared							Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken				
						C	P	Mn	Si	S			C	P	Mn	Si	S				Special		Comparative		
																					Sq. in. abraded	% of area of Head	Sq. in. abraded	% of area of Head	
Manganese	Glen Lyn M.P. 3402 On high Side of 9° Curve East Bound Track	4	85	A.S.C.E	Manganese Steel Co	.77	.06	.993	.25	.038									Apr 15th 1908	Test in progress 10-31-11	2 1/2 Months #	25	7.142			Approximate gross tonnage over Rails 38,000,000 Tons To Date
											Carnegie Bessemer		.49	.099	.90	.10	.04		Apr 15th 1908	Oct 15th 1909 All Bess. Rails Removed	18 Months			.825	23.592	Approximate gross tonnage 29,000,000 tons
											Bethlehem O. H.		.684	.026	.737	.138	.0386		Oct 15th 1909	Test in progress 10-31-11	12 Months			.10	2.86	Approximate gross tonnage 29,000,000 tons to Date

Pennsylvania Lines West of Pittsburgh North-West System [illegible] 187.

Record of Comparative Wear of Special Rail

Date of Report January 1912

Special Rail: Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Special Rail: Chemical Composition C	P	Mn	Si	S	Chemical Composition of Open Hearth (Standard Composition) Rail of 100 Lb. P.S. Section with which Special Rail was Compared C	P	Mn	Si	S	Special and Comparative Rails: Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken: Special Sq. in. abraded	Special % of area of Head	Comparative Sq. in. abraded	Comparative % of area of Head
Open Hearth Special High Silicon	Raby, Ind.	9	100	P.S.	Illinois Steel Co.	.72	.029	.80	.31	.039	.63-.72	.020-.039	.60-.80	.14-.20	.034-.053	July 11	—	5 mo.	.066	162	.073	155

Penna. Lines West of Pittsburgh. South-West System. Pittsburgh Division RAILROAD

Record of Comparative Wear of Special Rail

Date of Report Jan. 18th 1912

Special Rail: Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition: C	P	Mn	Si	S	Nickl	Chrom	Chemical Composition of Rail with which Special Rail was Compared: C	P	Mn	Si	S			Special and Comparative Rails: Date Laid	Date Removed	Length of Service at date of Report	Average Area Abraded of all the Sections taken: Special Sq. In. abraded	Special % of area of Head	Comparative Sq. In. abraded	Comparative % of area of Head	Abrasion per 1,000,000 tons of traffic
Havana Cuban Ore Open Hearth	O.C.Ry. W Leg of Y	31	85	P.S.	Penna Steel Co.	.805	.022	.87	.17	.035	.97	.21								7-11-10	Test in Progress	18 Mos.	.57	15.97			
Bessemer	O.C.Ry. W Leg of "Y"		85	A.S.C.E.	Carnegie								0.55	.07	1.05	.13		Specifications		7-1-07	10-9-07	3 Mos.			0.672	19.2	
"	" " "		"	"	"								0.51	.093	.88	1.03	.045	"		10-9-07	8-17-08	10 Mos.			0.68	19.5	.1859 in.
"	" " "		"	P.S.	Maryland								0.50	.077	.95	.091	.056	"		8-17-08	12-24-08	4 "			0.45	12.6	.3959 in
"	" " "		"	"	Cambria								0.52	.096	.90	.085	.090	"		12-24-08	8-2-09	7 "			0.645	18.07	.2359 in
Open Hearth "B"	" " "		"	"	Gary								0.65	.032	.69	.041	.041	"		8-2-09	7-11-10	11 "			0.772	21.62	.2259 in

Tonnage over Rail

Carnegie	37060713
Maryland	11350744
Cambria	27798760
Illinois	34418894

THE WHEELING & LAKE ERIE. RAILROAD 190

Record of Comparative Wear of Special Rail

Date of Report FEBRUARY 13, 1912.

Special Rail													Chemical Composition of CARNEGIE BESSEMER Rail of 90# A.S.C.E. Section with which Special Rail was Compared							Special and Comparative Rails							
Kind of Steel	Location	No. of Tons Laid	Weight per Yard	Type of Section	Manufacturer	Chemical Composition															Date Laid	Date Removed	Length of Service at ~~date of~~ Report LAST INSPEC	Average Area Abraded of all the Sections taken			
						C	P	Mn	Si	S	TITANIUM		C	P	Mn	Si	S							Special		Comparative	
																								Sq. In. abraded	% of area of Head	Sq. In. abraded	% of area of Head
FERRO-TITANIUM ALLOY 0.3 OF 1%	2° CURVE AT KENWOOD TOLEDO DIVISION	20	90#	A.S.C.E.	LACKAWANNA STEEL CO.	0.44 0.54	MAX. 0.10	0.90 1.10	0.13 0.20	MAX. 0.075	0.3 OF 1%		0.45 0.55	MAX. 0.10	0.80 1.10	MAX. 0.20					9-27-1910	IN TRACK	448 DAYS	0.12	3.24	0.09	2.43
FERRO-TITANIUM ALLOY	2° CURVE AT ADENA TOLEDO DIVISION	17	90#	A.S.C.E.	CARNEGIE STEEL CO.	0.46 0.56	MAX. 0.10	0.90 1.10	0.13 0.20	MAX. 0.075	0.3 OF 1%		0.45 0.55	MAX. 0.10	0.80 1.10	MAX. 0.20					9-8-1910	IN TRACK	370 DAYS	0.09	2.43	0.07	1.89

Appendix H.

EFFECT OF PIPING, CAVITIES AND POROUS SPOTS IN INGOTS ON THE FINISHED RAIL.

By J. R. Onderdonk, Engineer of Tests, Baltimore & Ohio Railroad System.

This paper is presented, not with the intention of furnishing any new information, but with the idea of presenting information of an historical nature, with a view to bringing together certain data bearing on the above subject.

During the years 1904 and 1905 the number of split heads became so serious on the Baltimore & Ohio that it was decided to make a special investigation as to their cause and, if possible, adopt a remedy.

It was noted that the heads of rails would split, sometimes breaking off the side of the head for distances of ten and fifteen feet, sometimes on the gage side, and sometimes on the outside. If the latter, the results were not usually serious, while if on the gage side, it was likely to cause a derailment.

Whenever these failures occurred it was observed that the now well-known dark streak appeared on the top of the rail, and our trackmen soon became expert in detecting these, and the rails were removed before complete failure; and it is due to the trackmen's vigilance that more of these rails have not caused trouble.

It was also noted that in some manufacturers' rails this defect was more pronounced than in others.

Being one of a committee to investigate this subject in 1905, we visited the different rail mills, and were told that this defect was due wholly to not having had the proper top discard.

In the meantime ingots were examined, and in one or two cases full ingots and blooms were shipped to the Baltimore & Ohio shops at Mt. Clare, where they were cut in two longitudinally, photographed and analyzed.

The first ingot split was reported November 18, 1912, and Fig. 1 shows the section through the center of this ingot, which was cooled in a vertical position without soaking.

Report No. 29, August, 1912.

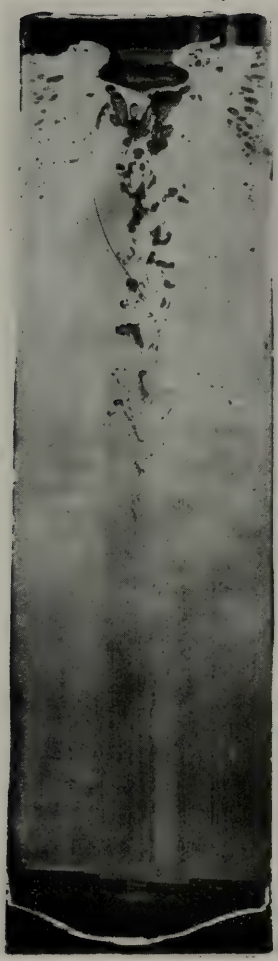


FIG. 1.

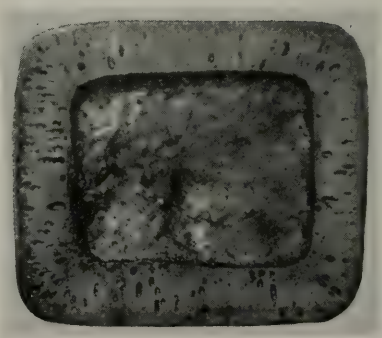


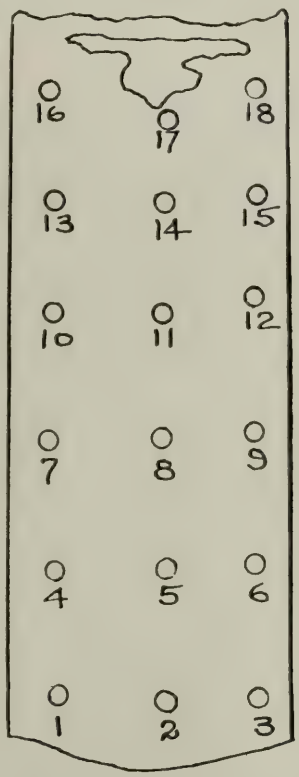
FIG. 2.

Fig. 2 is a section cut off the top, showing it to be water cooled.

Table No. 1 shows the result of the chemical analyses, samples 17, 14, 11, 8, 5 and 2 being taken along the center axis and the others at either side, as shown on the sketch.

TABLE NO. 1—CHEMICAL ANALYSES.

Drillings taken from hole No.	Carbon	Sulphur	Phos.	Mang.	Position in Ingot
1	.57	.041	.085	1.15	95 per cent.
2	.56	.033	.076	1.14	from
3	.60	.040	.089	1.15	top
4	.60	.041	.087	1.14	80 per cent.
5	.61	.037	.079	1.17	from
6	.61	.041	.086	1.14	top
7	.62	.041	.088	1.13	60 per cent.
8	.60	.040	083	1.14	from
9	.61	.041	.090	1.13	top
10	.60	.038	.091	1.15	40 per cent.
11	.60	.038	.088	1.13	from
12	.60	.040	.090	1 13	top
13	.60	.039	.091	1 08	22 per cent.
14	.61	.040	.087	1.09	from
15	.60	.041	.090	1.08	top
16	.66	.034	.075	1.05	5 per cent.
17	.99	.091	.179	1.17	from
18	.62	.032	.066	1.17	top



No. 17 was drilled near the edge of the large cavity and shows considerable segregation. The carbon is about one-third above the average, the sulphur is about two and a half times the average, the phosphorus is about double the average, while the manganese is fairly uniform in all.

Leaving out test No. 17, the other analyses show the following variations:

Carbon	.56	to .66	per cent.
Sulphur	.032	to .041	per cent.
Phosphorus	.066	to .091	per cent.
Manganese	1.08	to 1.17	per cent.

If we discard the upper ten per cent., the variations run as follows:

Carbon	.56	to .62	per cent.
Sulphur	.033	to .041	per cent.
Phosphorus	.076	to .091	per cent.
Manganese	1.08	to 1.17	per cent.

If we discard the upper third, or what is equivalent to a top discard of 33 per cent., the variations run as follows:

Carbon	.56	to	.62	per cent.
Sulphur	.033	to	.041	per cent.
Phosphorus	.076	to	.091	per cent.
Manganese	1.13	to	1.17	per cent.

FIG. 3.

Ingot 1A.—Cooled in vertical position without soaking. Middle slab 1A4, longitudinal section. Surface 1 inch from axis of ingot or 8½ inches in from exterior surface. Showing blowholes and shrinkage cavities, also transverse shrinkage crack extending nearly across slice near middle of height of ingot.

FIG. 4.

Ingot 1A.—Cooled in vertical position without soaking. Outside slab 1A2, longitudinal section. Surface 7 inches from axis of ingot or 2½ inches in from exterior surface. Showing blowholes and short transverse shrinkage crack near middle of height of ingot.

This shows that there is very little difference in the chemical composition of this ingot as far as a small or large discard is concerned, although it is possible a greater variation might be found if drillings had been taken at closer intervals.

Figs. 3, 4, 5, 6 and 7 show photographs of split ingots, the work being done in 1909 at the Watertown Arsenal, and are given to show the difference in sections cut from ingots cooled with and without soaking, also the difference between sections taken through the center and from near the sides.

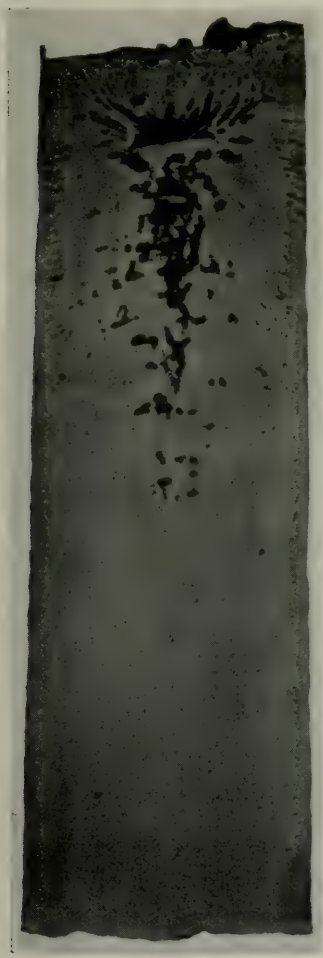


FIG. 5.

Ingot 1B.—Soaked and then cooled in vertical position. Half ingot 1B1, axial longitudinal section. Showing blowholes and shrinkage cavities.

FIG. 6.

Ingot 1B.—Soaked and then cooled in vertical position. Outside slab 1B2, longitudinal section. Surface 7 inches from axis of ingot or 2½ inches in from exterior surface. Showing blowholes in the steel.

FIG. 7.

Ingot 1A.—Cooled in vertical position without soaking. Quarter ingot 1A6, longitudinal section. Showing blowholes and shrinkage cavities, also transverse shrinkage crack near middle of height of ingot.

After the ingot work was completed, we were told by the manufacturers that these ingots would not represent the condition of the steel that went into the rail, as the ingots were not allowed to get cold, but were placed in the soaking pit, then rolled, and never became cold until it had been finished into a rail, and all these cavities would be cleaned up. At the time of selecting the ingots, this point was in a measure anticipated, and the bloom 9¼ in. x 9¼ in. representing the upper third of an ingot was also sent to Mt. Clare and split.

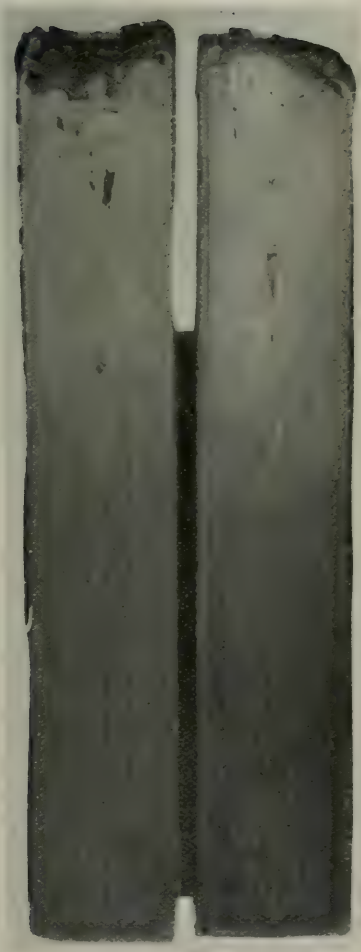


FIG. 8.

FIG. 9.

Fig. 8 shows this bloom after passing the blooming rolls, split, and the cavities seem, to a certain extent, to have disappeared. One of these pieces was then etched with acid and the one on the right, No. 2, Fig. 9, shows that this weak and defective material was still there.

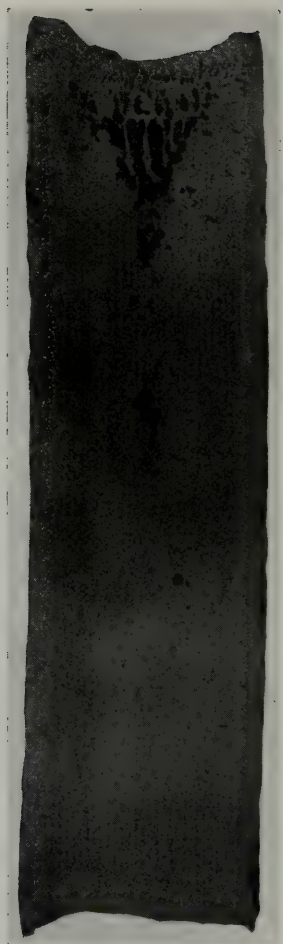


FIG. 10.

From Ingot 5D.—Third blooming pass. Axial longitudinal section.

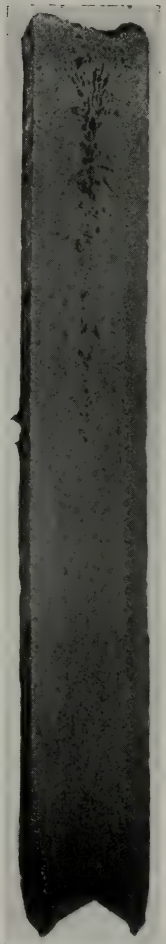


FIG. 11.

From Ingot 5E.—Sixth blooming pass. Axial longitudinal section.

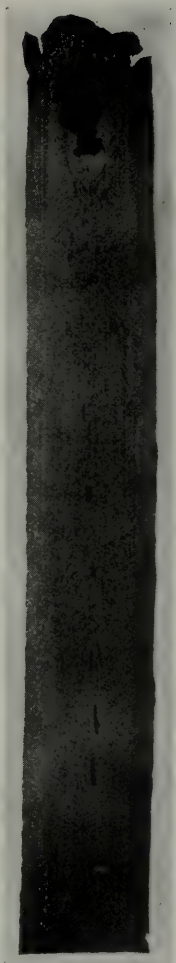


FIG. 12.

From Ingot 5F.—Ninth blooming pass, upper half.

It will be noted that 33 per cent. discard will not get rid of all the cavities in the material shown in Figs. 1, 4, 6, 7, 10, 11 and 12.

Figs. 10, 11 and 12 are of blooms after different number of passes, tested by the Watertown Arsenal, showing that even after the ninth blooming pass there were considerable defects in the upper half of the ingot.

FIG. 13.

FIG. 14.

Fig. 13 shows the so-called pipeless ingot reported in Mr. Wickhorst's Report No. 25.

Fig. 19 shows the same ingot, the surface having been polished and etched at Mt. Clare. This brings out the irregularities in the steel at the center core, which although not very marked in this ingot, still such irregularities undoubtedly have a close connection with the split heads and webs in rails other than the "A" rails.

To show the effect of making a large crop from the top of the ingot, Fig. 20 shows the rail failures in service for each year's rolling from one certain mill, their failures being plotted per 1,000 tons laid, for convenience.

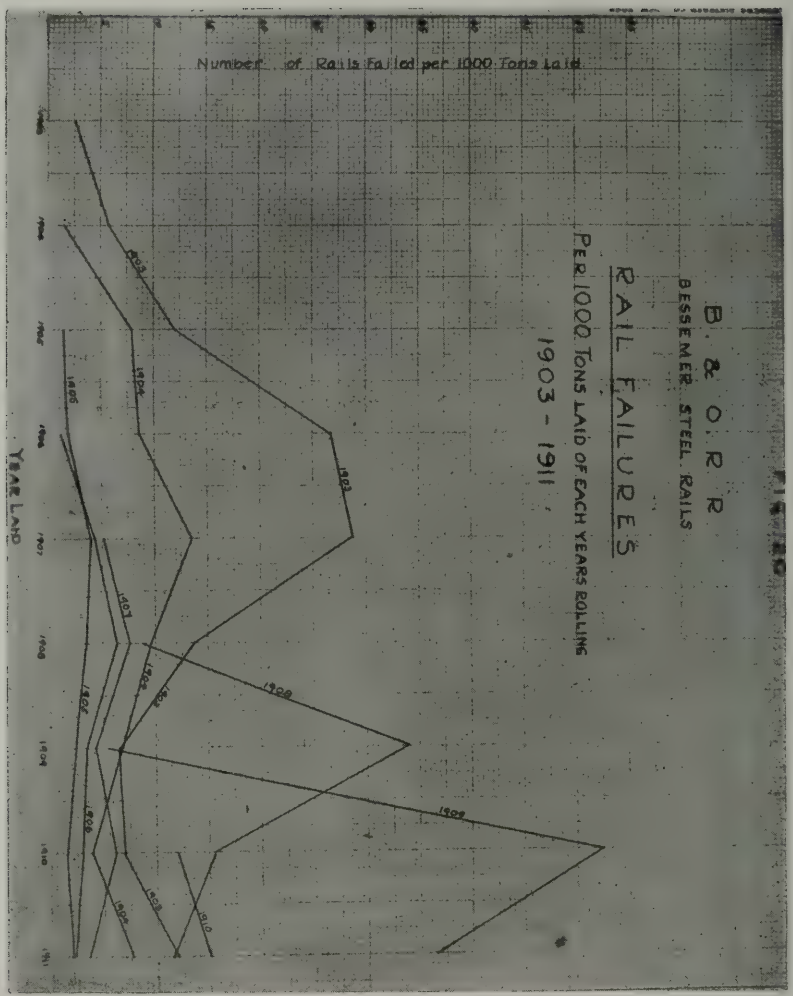


FIG. 20.

The ordinates represent the number of failures per 1,000 tons for each year's rolling.

Those rolled in 1903 had about 8 per cent. top discard; in 1904, about 9 per cent.; in 1905, about 33 per cent.; most of those rolled in 1906 and 1907, about 33 per cent.; in 1908, about 6 per cent.; in 1909, about 9 per cent.; in 1910, about 20 per cent.

From this particular mill the best results were from the 1905 rollings, where a discard of 33 per cent. was made; the 1906 and 1907 rollings also show up well, but all the ingots did not have the 33 per cent. discard;

1908 and 1909 rollings show up badly and had small top discards; 1910 rollings, from which a 20 per cent. discard was made, does not show up as well as the years when 33 per cent. discard was made, but better than when only 10 per cent. discard was made.

Other makes of rails in the same service, with about 12 per cent. discard, give as good results as others with 33 per cent. discard, all of which goes to show the desirability of a certain discard, but that a fixed discard of large proportions is not necessary at all mills, and possibly not all ingots, and we come down to the proposition that the blooms should be cut back until solid metal is reached, which does not seem to be accomplished with the present method of shearing, and relief should be looked for by improving the methods of casting the ingot, so as to get a uniform solid ingot, with any piping or irregularities very near the top.

Appendix I.

INVESTIGATION OF SILVERY OVAL SPOTS, SOMETIMES CALLED "TRANSVERSE OR INTERNAL FISSURES," IN RAIL HEADS.

By W. C. Cushing, Chief Engineer Maintenance of Way, South West System, Pennsylvania Lines West.

During the past two years, a new type of rail failure has been brought to the attention of those interested in the manufacture and service of rails for steam railways, several articles having been written to describe recent cases of such failures, and various theories have been suggested as an explanation of the cause. This type of failure may or may not be new, but it seems to be a fact that particular attention had not been called to it until within the last year, when Mr. James E. Howard, Engineer-Physicist of the Bureau of Standards, made his examination of the rail which caused the wreck on the Lehigh Valley Railroad near Manchester, N. Y., August 25, 1911.

Nineteen rails with defective spots of this character in the head have been discovered on the Pennsylvania Railroad System, one or two of them being in rails which had not yet failed, the examination having been made on purpose to ascertain the appearance of these spots before actual failure, and the results of their examination, made at the Altoona Laboratory of the Pennsylvania Railroad, have been described in a very interesting and entertaining manner by Mr. C. D. Young, Engineer of Tests, in his report to the General Superintendent of Motive Power, Mr. J. T. Wallis, a member of the Rail Committee of the Pennsylvania Railroad System. It is a very timely and valuable contribution to the subject, and is submitted herewith for the information of the members of our Association.

Mr. Young and Mr. F. N. Pease, Chemist, have shown by these examinations that the spot contains slag, which produces a weak place during the manufacture of the rail. It is very likely true, as some have said, that the fracture is developed in service, intimating that extreme severity of service is the main cause for failure. It is clear from these studies that one principal cause of this defect is the inclusion of slag during manufacture, and the subsequent service is only one agent in its development. Indeed, it has been stated positively and authoritatively to the writer that such a spot has been found in a rail which had never been in service. It seems to the writer, therefore, that the assignment of extreme severity of service as the real cause of this type of failure was a mistake, and that it is evident from these examinations that the cause is due to defects of manufacture. It is a fact that the majority of

Report No. 31, Oct. 1912.

these failures have occurred in the product of one manufacturer. The time in service of those rails which failed near Colonia, on the New York Division, was about a year and nine months, while one from the Ohio Connecting Railway was about eleven and one-half months in service, another one a year and two months and three of them a year and seven months. It is essentially the duty of rails to be severely punished and stand hard service and it is a necessary part of the work for which they are purchased. Some, in discussing the question of rail failures, seem to think it is necessary to handle and treat rails very tenderly, and that if, for instance, there is the least inequality of bearing area on a cross-tie, it will be found to be the main cause of base failures. This is to suppose that a wooden cross-tie is harder than a piece of rail steel, which is absurd. If a rail will not stand considerable rough handling we do not want it, for it is too tender for the service demanded of it. The numerous cases of proved defects, in the shape of rolling seams and laminations in the bases of rail, clearly prove that improvements in the manufacture of rails are necessary at those points, just as the presence of slag in the silvery oval spots of the nineteen rails examined at the Altoona Laboratory proves that improvements in manufacture are necessary to eliminate the trouble from fractures caused by the presence of slag has been responsible for a great many of the various defects of rails. It is well known from the statistics that have been published from time to time that the percentage of rail failures to the total in use is very small, showing clearly that the great majority of the rails perform the service for which they are intended, but it is necessary to bring about such improvements in the manufacture that this percentage will be so small that no train wrecks will be caused by them. In this connection, it is noteworthy how much effort was necessary to fracture the rails as described on Sheets Nos. 2799 and 2800 and illustrated in Photograph No. 1708. In several cases it took repeated falls from a height of 18 feet on a pile of axles to cause fracture.

The rails laid on the Ohio Connecting Railway were for the purpose of making a special abrasion test in comparison with rails of other kinds, both Bessemer and Open-Hearth, and with different proportions of chemical constituents. The detailed information in regard to the different rails tested is given in Sheet No. 1, and on that sheet will be found the relative comparison in square inches of abrasion per 10,000,000 tons of traffic. The Pennsylvania Steel Company's 85-lb. rails of Mayari ore were found to be very hard, and gave witness to this by outlasting very considerably all of the others tested, the abrasion from the head being .09 of a square inch per 10,000,000 tons, as against .18 of a square inch per 10,000,000 tons of traffic for the next lowest, a Bessemer steel of ordinary composition.

Inasmuch as the rail represented by T. D. No. 564 is described in considerable detail by Mr. Young, the writer submits, in Sheet No. 2, the laboratory report of the tests made, in order that the location of the test pieces in the rail section may be understood, and in Sheets Nos. 3 and 4, the deep and light etchings and microphotographs of the sections. A longitudinal crack in the head is shown in microphotograph "B."

PENNSYLVANIA LINES WEST OF PITTSBURGH.

Southwest System.

COMPARISON BETWEEN DIFFERENT KINDS OF RAIL WHICH HAVE WORN OUT ON WEST LEG OF NORTH END, OHIO CONNECTING BIRDGE, 8 DEG. CURVE.

Sheet No. 1. June, 1912.

	Carnegie-Bess. 85 A. S. C. E.		Maryland Bess. 85, P. S.	Cambria Bess. 85 P. S.	Illinois O. H.-B. 85 P. S.	Penna. Steel Mayari 85 P. S.	Carnegie O. H.-A. 85 P. S.	Gary O. H.-A. 85 P. S.
	Laid 7-1-'07 Rem. 10-9-'07	Laid 10-9-'07 Rem. 8-17-'08	Laid 8-17-'08 Rem. 12-24-'08	Laid 12-24-'08 Rem. 8-2-'09	Laid 8-2-'09 Rem. 7-11-'10	Laid 7-11-'10 Rem. 3-11-'12	Laid 3-11-'12 Rem.	Laid 3-11-'12 Rem.
Time in Service	3 Mo. 8 days	10 Mo. 8 days	4 Mo. 7 days	7 Mo. 8 days	11 Mo. 9 days	20 Mo. 0 days		
Per cent. of area of Head Abraded:								
Average	19.2	19.5	13.9	18.07	21.62	16.67	.....	.....
Maximum	29.4	22.6	17.08	24.1	41.46	29.69	.....	.....
In 6 weeks	.....	.....	6.78	3.59	4.48	5.02	3.92	4.48
In 16 weeks	.....	.....	13.38	6.96	8.87	6.44	7.56	8.96
In 32 weeks	.....	.....	.....	18.07	12.61	8.40	.....	.....
In 40 weeks	.....	.....	.....	.....	14.29	9.24	.....	.....
In 1 Year	.....	.....	.....	.....	.....	11.57	.....	.....
In 62 weeks	.....	.....	.....	.....	.....	12.61	.....	.....
In 1 year, 6 months	.....	.....	.....	.....	.....	15.97	.....	.....
In 84 weeks	.....	.....	.....	.....	.....	15.97	.....	.....
Abrasion per 10,000,000 tons	.....	.180 sq. in.	.390 sq. in.	.23 sq. in.	.22 sq. in.	.09 sq. in.	.....	.....
Approximate tonnage over rail, total	.....	37,060,713	11,350,744	27,798,760	34,414,894	67,216,756	.....	.....
Approximate tonnage over rail, per diem	.....	119,550	87,313	126,358	100,335	110,372	.....	.....
Chemical composition:	Specific	Specific						
C. by Ladle Anal	0.55	0.51	0.50	0.52	0.65	0.805	.....	.....
P. by Ladle Anal	0.07	0.093	0.077	0.096	0.032	0.022	.....	.....
Mn. by Ladle Anal	1.05	0.88	0.95	0.90	0.69	0.87	.....	.....
Si. by Ladle Anal	0.13	0.103	0.091	0.085	0.14	0.17	.....	.....
S. by Ladle Anal	.....	0.045	0.056	0.090	0.041	0.035	.....	.....
Nickel by Ladle Anal	.....	.....	.....	.....	.....	0.97	.....	.....
Chromium by Ladle Anal	.....	.....	.....	.....	.....	0.21	.....	.....
C. by Rail Anal	.....	.....	0.420-0.672	0.488-0.532	0.679-0.685	0.820-0.860	.....	.....
P. by Rail Anal	.....	.....	0.060-0.121	0.092-0.110	0.037-0.041	0.023-0.027	.....	.....
Mn. by Rail Anal	.....	.....	0.71 -0.95	0.92 -0.109	0.69 -0.72	0.82 -0.89	.....	.....
Si. by Rail Anal	.....	.....	0.042-0.066	0.105-0.122	0.119-0.123	0.170-0.182	.....	.....
S. by Rail Anal	.....	.....	0.051-0.136	0.071-0.097	0.027-0.028	0.025-0.035	.....	.....
Nickel by Rail Anal	.....	.....	.....	.....	.....	0.92 -1.00	.....	.....
Chromium by Rail Anal	.....	.....	.....	.....	.....	0.26 -0.29	.....	.....
Tensile strength, lbs. per square inch	.....	.....	95,800-106,800	111,350 119,620	115,790 117,470	112,695 152,550	.....	.....
Elastic limit, lbs. per square inch	.....	.....	47,200-53,600	68,970-75,800	68,310-82,270	75,420-93,150	.....	.....
Elongation in 2 inches	.....	.....	0.38-0.52	0.30-0.36	0.28-0.29	0.02-0.13	.....	.....
Elongation, per cent. of original length	.....	.....	19 to 26	15 to 18	14 to 14.5	1 to 6.5	.....	.....
Reduction, per cent. of original section	.....	.....	23.6-36.6	24.74-31.96	21.14-22.87	1.02-10.81	.....	.....

SHEET No. 2.

Report No. 661 M. W. 34 F. R 13 1912 10½ x 8 Copying Ink

T.D.No.564 PENNSYLVANIA RAILROAD COMPANY
P., B. & W. R. R. N. C. RY. W. J. & S. R. R.

LABORATORY REPORT

CHEMICAL AND PHYSICAL EXAMINATION OF RAIL AND OTHER TRACK MATERIAL

Referred to in letter L.R.Zollinger to J.T.Wallis, dated March 22 and May 27, 1912.

Laboratory No. 24058-9-60 Sample Represents Rail which failed near Colonia, N.Y.Division, 3090 ft. west of M.P.21. 2-2-12. P.S.Sec.Beth.11-10. Heat No. not found. 100-lb. rail. Break - Transverse Fissure.

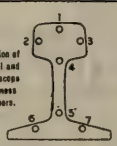
Place and Date Altoona, Pa., June 19, 1912

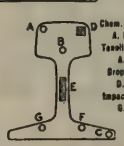
CHEMICAL ANALYSIS									PHYSICAL TESTS				
Location of Borings	C.	Mn.	P.	Si.	S.				Tensile Strength Lbs. Per Sq. In.	Elastic Limit Lbs. Per Sq. In.	Elongation Per Cent. In 2 Ins.	Reduction of Area—% of Original Sec.	Character of Fracture
Head	.80	.60	.029	.160	.022				101950	60050	3	2.6	G
Neck	.82	.60	.032	.165	.024								
Foot	.79	.60	.025	.155	.022								
Avg.	.80	.60	.029	.160	.023								

DROP TEST. SUPPORTS 12" APART. WEIGHT OF TUP, 50 LBS.										
Test Piece at "D" 33/32" x 33/32"					Test Piece at "E" ½" x 1"					Impact Test No. of Double Vibrations
Blows at 5 Ft.	Blows at 10 Ft.	Blows at 15 Ft.	Initial Deflec.	Accum. Ft. lbs.	Blows at 3 Ft.	Blows at 6 Ft.	Blows at 10 Ft.	Initial Deflec.	Accum. Ft. lbs.	
1	-	-	-	250	5	5	10	1"	7250	738

Location		1.	2.	3.	4.	5.	6.	7.	Avg.
Hardness Number	Brinell	254	256	256	272	269	254	269	262
	Scleroscope	32	32	32	32	33	32	31	32

Location of Brinell and Scleroscope Hardness Numbers.





Chem. Analysis A, B, C.
Tensile Tests A, B.
Drop Tests D, E.
Impact Tests G, F

REMARKS:—

A hard rail showing a high Brinell figure, and brittle properties, as indicated by the low elongation, reduction of area, etc. A well-developed transverse fissure was observed at the break. A longitudinal crack, visible only under the microscope, is also shown in photomicrograph "B" in cross-section.

APPROVED:—

(Signed), P.N.Pease,
Chemist, P. R. R.

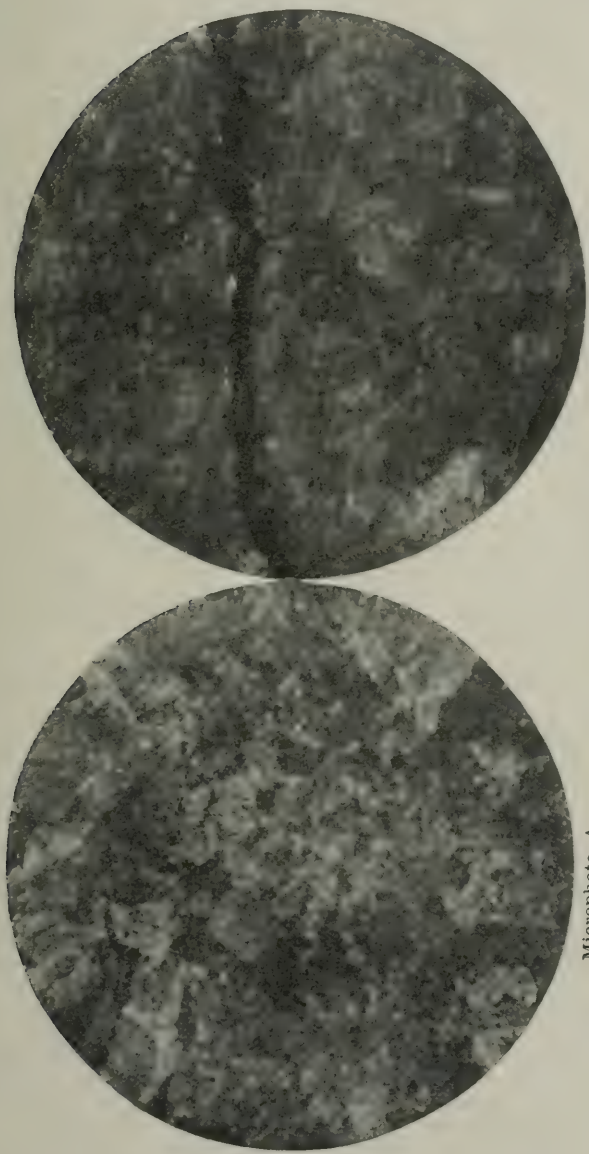
SHEET No. 3.

Deep Etching.
Chem. Lab. No. 24058-9-60. T. D. No. 564.

SHEET No. 4.

Light Etching.

SHEET No. 4-a.



Microphoto A. Microphoto B.

100 Diameters.

CHEM. LAB. No. 24058-9-60. T. D. No. 564.

PENNSYLVANIA RAILROAD TEST DEPARTMENT.

Altoona, Pa., July 24, 1912.

REPORT ON TRANSVERSE OR INTERNAL FISSURES IN RAILS.

To Mr. J. T. Wallis, General Superintendent Motive Power, by C. D. Young, Engineer of Tests.

Much interest has developed since the report of Mr. Howard on the Lehigh Valley wreck, in regard to the so-called transverse fissure causing failure of rails in service.

In our tests during the investigation of broken rails we have found them in test pieces in the following cases:

T. D. No. 401, from Philadelphia Division, rolled by Bethlehem Steel Company.

T. D. No. 524, from Philadelphia Division, rolled by Bethlehem Steel Company.

T. D. No. 630, from Pittsburgh Division, rolled by Lackawanna Steel Company.

T. D. No. 694, from Ohio Connecting Bridge, rolled by Pennsylvania Steel Company.

In every case these were found in the drop test specimen, with but one exception, viz.: No. 694, which was discovered in the tensile test piece.

We have been taking our specimens for drop test from the gage side of the rail, but cannot say positively at this time whether or not an error was not made in taking this tensile test piece from the gage side of the rail.

In addition to the above-mentioned rails we have received a number of samples which showed a pronounced transverse fissure in the original fracture.

We received from Mr. Zollinger ten (10) Bethlehem Open-Hearth rails, which failed in track near Colonia on the New York Division, some of which showed the fissures in the original fracture, and one rail from the same lot which had not been placed in service. These which failed were one year and nine months in service, five were B rails, two were C, one was D, one was E and one unknown. These rails bear T. D. Nos. 555 to 564 inclusive. Later we received another rail from the same lot which had not been in track and it was given T. D. No. 910. The first test made on these rails was to saw the rail longitudinally just below the head and place the head in tensile machine on supports 24 inches apart with the gage side down, applying the load in the center between supports. This test was made on rails T. D. Nos. 564 and 565. In only one case did the transverse fissure appear at the point where load was applied, but the rail broke at a location outside of the points of support, at the same time failure occurring at the point at which load was applied. These sudden fractures in every case showed the beginning of this transverse fissure.

After this test some of the smaller pieces were broken under steam hammer and two small fissures were disclosed. The location of the fracture is shown on Sheet No. 2798, and the appearance of the internal fissures is shown by photographs from Plates 1705, 1706 and 1720.

The rail which had not been in service, T. D. No. 565, was subjected to the same tests, but no internal fissures were found, and the appearance of the test after load was applied is shown on Plate 1708. Here you will note that the rail bent considerably before breaking. This we believe is due to the fact that it was softer chemically than the other

rail tested, T. D. No. 564, being lower in carbon and manganese. The physical results all show a much softer steel.

All other rails from this lot were subjected to a drop test, each rail being raised by crane to a height of about 18 feet and allowed to drop in a horizontal position on a pile of driving axles. It was believed that this sort of drop test would bring out any transverse fissures that might be in the interior of the rail. Under this test only one rail showed any signs of this fissure, it being found in the same rail that was tested under tensile machine. The results obtained from this drop test are shown on Sheets Nos. 2799 and 2800, and the transverse fissures discovered are illustrated by photographs on Plates Nos. 2215, 2216, 2217 and 2218. Brinell tests were also made on the side of head and tread of rail, the results of which are shown on Sheet No. 2801. These results also show that the rail which had not been in service was a softer rail. Some of the original fractures in this rail are shown by photographs from Plates Nos. 2285, 2286 and 2287.

Other rails were received from Mr. Cushing which had been in service on the Ohio Connecting Bridge, some of which had failed on account of this transverse fissure. These are designated by T. D. Nos. 452, 453 and 454. Photographs of two are shown by Plates Nos. 2287 and 2288.

In addition to the ones mentioned above ten (10) rails were removed from service at the same point, but only one, T. D. No. 694, showed any indication of this defect. This fissure was discovered in tensile test specimen.

In addition to our regular tests of these rails the head was cut from the portion remaining after taking samples for our routine tests and broken under a steam hammer. None of the samples tested disclosed any internal fissures.

All of the rails in which these fissures were discovered were made from a chemical hard steel and in physical tests it was brittle.

We give on Sheets Nos. 2803 and 2804 the results of our regular investigation of these rails. It will be noted that the rails having fissures did not differ materially in chemical or physical results from those which did not have the fissures in them. It was thought that the high carbon content might tend to the formation of cementite in the steel and certain specimens were prepared for microscopic examination, etching them with sodium picrate in order to develop this constituent. Some slight indications of it were found, but not sufficiently pronounced to photograph or to justify in drawing the conclusions that the failure was due to the cementite being present around the grains. We did find, however, considerable slag in these specimens.

It will be noted in all photographs that in addition to the variation in size, indicating their growth, that there is a distinct center around which the fissure extends radially and this is most apparent in the fissures which had not extended to the exterior of the rail, but were disclosed by sudden fracture. The specimens for microscopic examination were therefore cut down to this center and examined on the longitudinal section of the rail. Sheets 2805 and 2806 show photographs taken from one specimen and Sheet 2807 shows microphotographs taken from two other specimens. On Sheet No. 2805 the edge of this fissure starts off on another plane following slag spots. The other photographs are all taken very close to the edge of the fissure and all show pronounced slag lines.

We show on Plate No. 2297 the transverse fissure developed in rail T. D. No. 694 in the tensile specimen. For comparison, on Plate No. 2298, we show the appearance of the detail fracture such as is produced on a specimen when tested in the revolution machine under alternating stresses. In the revolution machine the detail fracture starts from the outside and extends towards the center until the sudden fracture occurs. It will be

noted, however, that the fracture shows certain lines radiating from the center, and in this regard it resembles closely the transverse fissure starting from the inside of the rail.

Detail fractures sometime show concentric rings, but under certain conditions these lines are not concentric, but as in the case above noted they are radial. We therefore, believe that these failures are all due to a detail fracture beginning in the interior of the rail at a point where it is weakened by the presence of slag, and also at the point where the maximum load comes on the head. This conclusion seems to be justified by the fact that in all cases which we have examined the fracture starts on the gage side of the rail just inside the center line of the head.

Sheets No. 2803 and 2804 show that certain rails giving approximately the same physical and chemical properties did not develop this same defect of transverse fissure which was found in some other rails in the group, and therefore, it would seem that the tests to which we subject the rail would not at all times be a clear indication of whether fissures might be expected. This would seem to indicate that either mill practice, impure steel or the service to which the rail is subjected would have a bearing upon the development of this defect. One of the predominating features found in all of the rails with transverse fissures is the presence of slag close to what we think is the start of the defect. We, therefore, believe that the statement is justified that this entrailed slag is the fundamental cause for the defect in connection with the chemical and physical properties which the steel possesses.

The above, together with the information shown on Sheets No. 2854 to 2856, which is an analysis of 19 Open-hearth rails showing transverse fissures in service, leads us to conclude:

(1) Steel which is chemically hard and low in ductility is farther weakened by the presence of slag and at such points rupture occurs which will ultimately, by detail fracture, result in complete failure of the rail.

(2) If this kind of failure is to be reduced or entirely avoided, the proper procedure would seem to be to lower the chemical hardening constituents in the steel, in order to raise the ductility and reduce or attempt to eliminate the presence of slag.

PENNSYLVANIA RAILROAD COMPANY

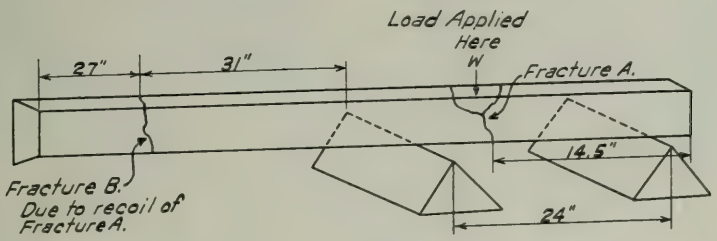
TEST DEPARTMENT

SHEET No 2798 REPORT No. 12-142

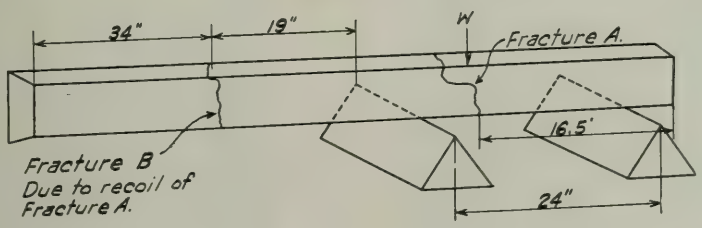
ALTOONA, PA. 4-17-12.

TRANSVERSE TEST OF RAIL HEAD.

TEST No. 1



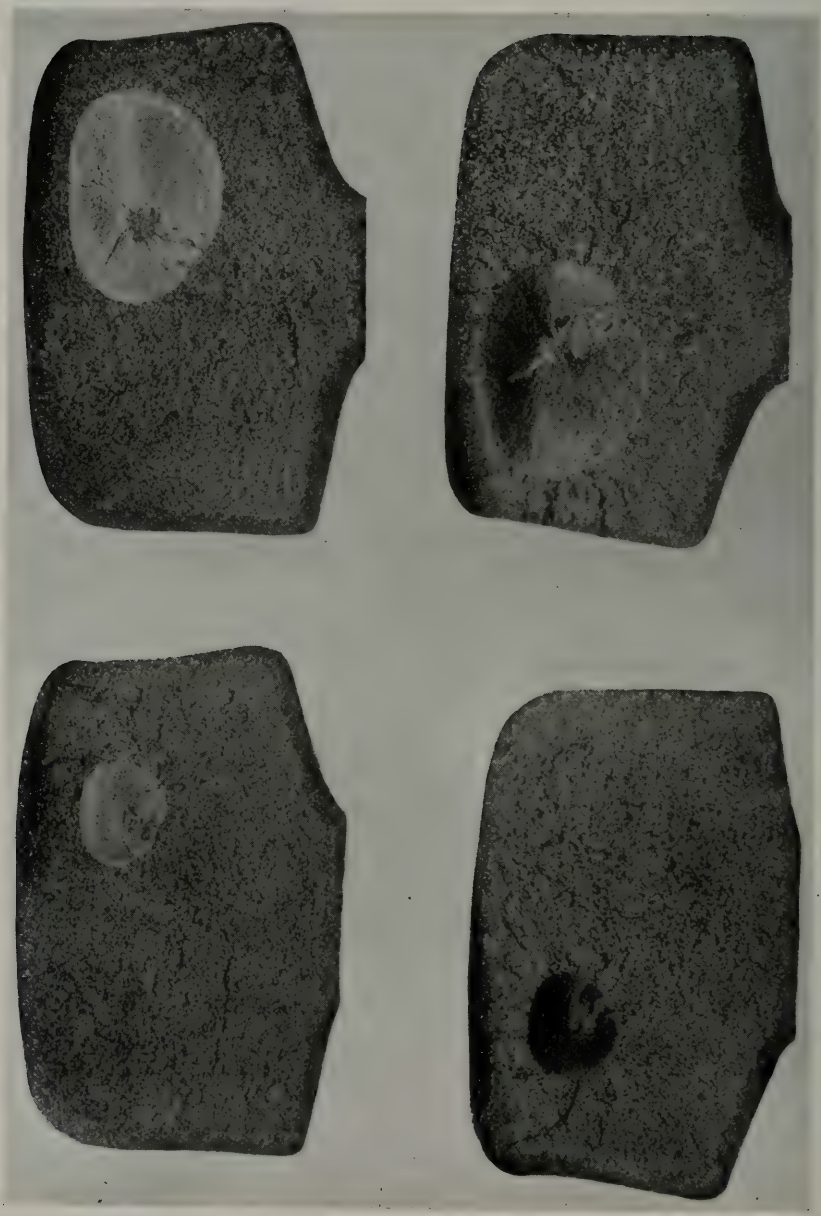
TEST No. 2



Fractures A and B occurred simultaneously in both Tests Nos. 1 and 2.

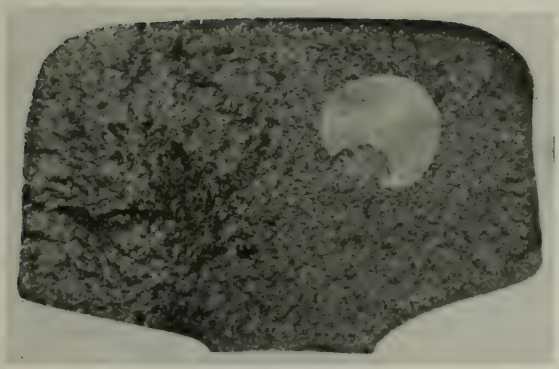
Sheet No. 2798.

PLATE 1705.



Rail T. D. No. 564 Broken in Tensile Machine. Internal Fissure at Point Outside of Supports.

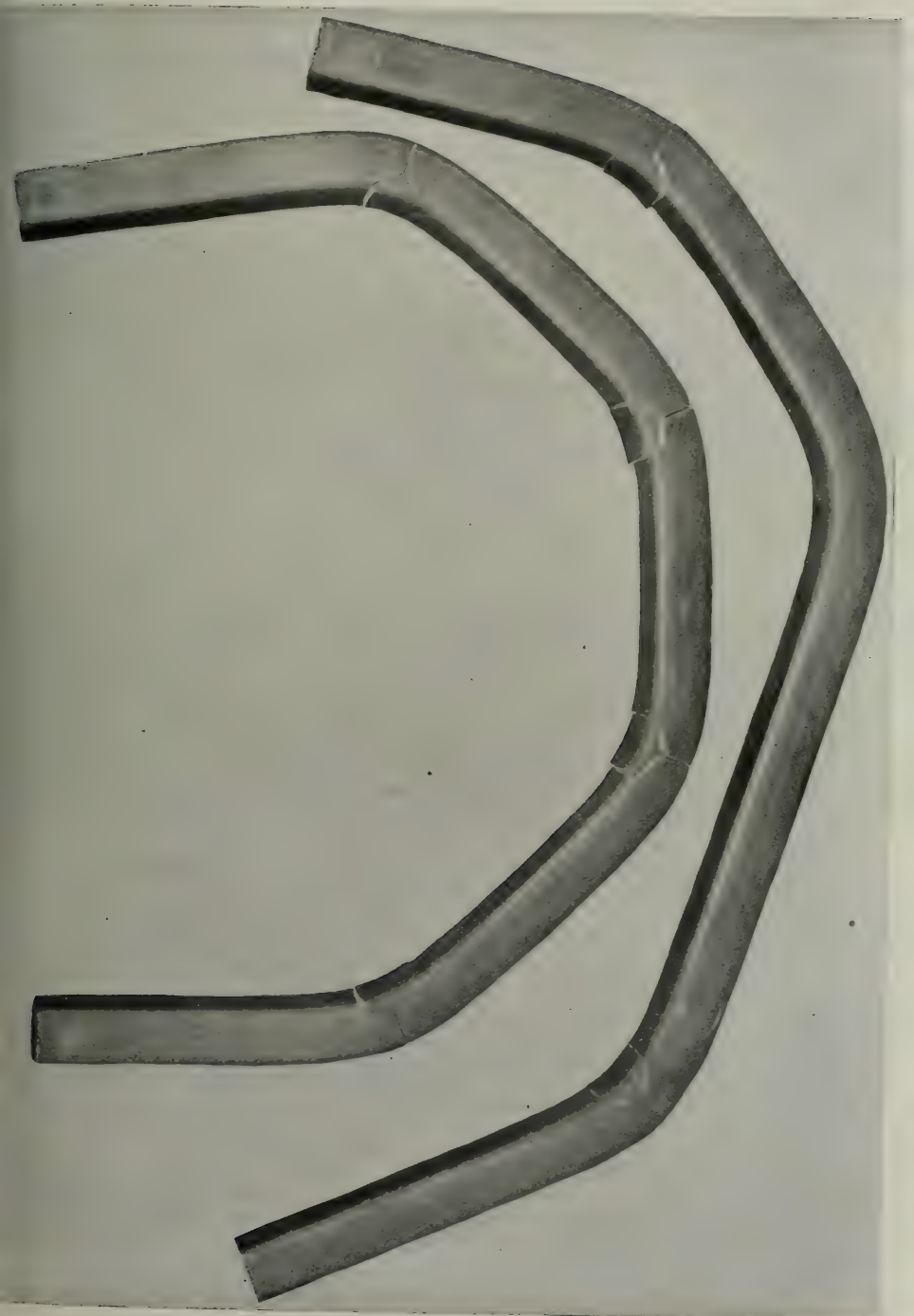
PLATE 1706.



RAIL T. D. No. 564 BROKEN IN TENSILE MACHINE. SHOWING INTERNAL FISSURES AT POINT OF APPLICATION OF LOAD.

PLATE 1729.

RAIL T. D. No. 564 BROKEN UNDER STEAM HAMMER. SHOWING INTERNAL FISSURES.



RAIL T. D. No. 565 WHICH HAD NOT BEEN PLACED IN TRACK. APPEARANCE OF RAIL AFTER LOAD WAS APPLIED AT DIFFERENT POINTS ON SUPPORTS 24 IN. APART IN TENSILE MACHINE—GAGE SIDE DOWN.

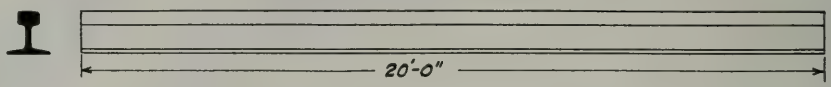
PENNSYLVANIA RAILROAD COMPANY

TEST DEPARTMENT

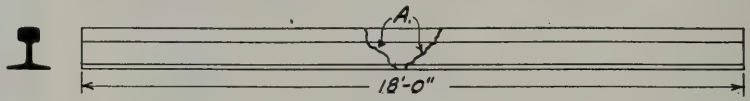
SHEET No. 2799 REPORT No. 12-142

DROP-TEST OF RAILS FROM COLONIA, N.Y. ALTOONA, PA. 7-10-12.

T.D. No. 562. DROPPED 4 TIMES 3 ON BASE - 1 ON HEAD.
NO BREAK. CRUSHED HEAD.

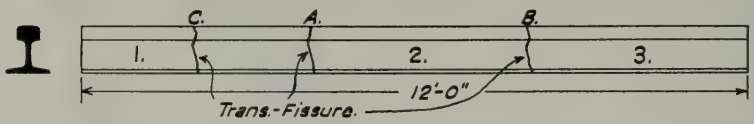


T.D. No. 563. DROPPED 2 TIMES BROKE AT "A."

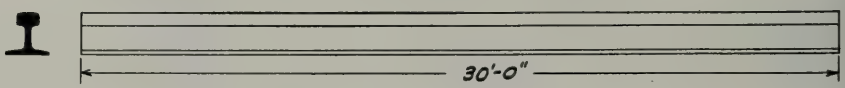


T.D. No. 564. DROPPED 1 TIME BROKE AT "A." PIECES 1 AND 2
DROPPED ONCE AGAIN EACH - NO BREAK.

T.D. No. 564. DROPPED 1 TIME BROKE AT "A" AND "B." PIECE MARKED
1 DROPPED AGAIN - BROKE AT "C." 2 DROPPED TWICE - NO BREAK.



T.D. No. 910. DROPPED 3 TIMES - NO BREAK - NEW RAIL.



NOTE:-
18' Drop

Sheet No. 2799.

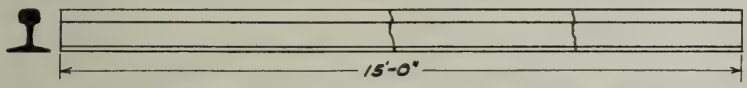
PENNSYLVANIA RAILROAD COMPANY

TEST DEPARTMENT

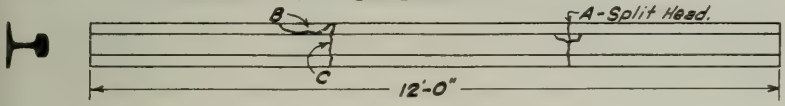
SHEET No. 2800 REPORT No. 12-142

DROP-TEST OF RAILS FROM COLONIA, N.Y. ALTOONA, PA. 7-10-12.

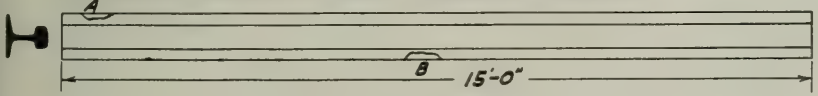
T.D. No. 556. DROPPED 1 TIME. BROKE 2 PLACES. SPLIT HEAD



T.D. No. 557. DROPPED 3 TIMES. BROKE AT "A" 1st. BLOW, AT "B" 2nd. BLOW - AT "C" 3rd. BLOW.

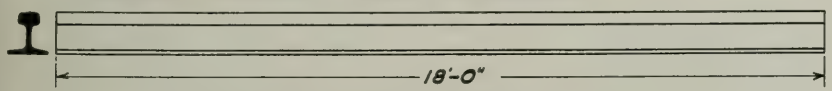


T. D. No. 558. DROPPED 2 TIMES. BROKE AT "A" AND "B".

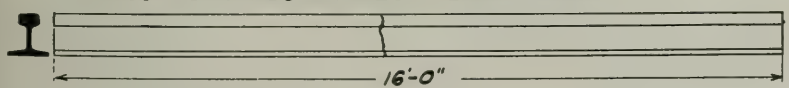


T.D. No. 559 "A" DROPPED 3 TIMES "B" 2 TIMES

T.D. No. 560. DROPPED 3 TIMES NO BREAK.



T.D. No. 561. DROPPED 2 TIMES CLEAN BREAK.



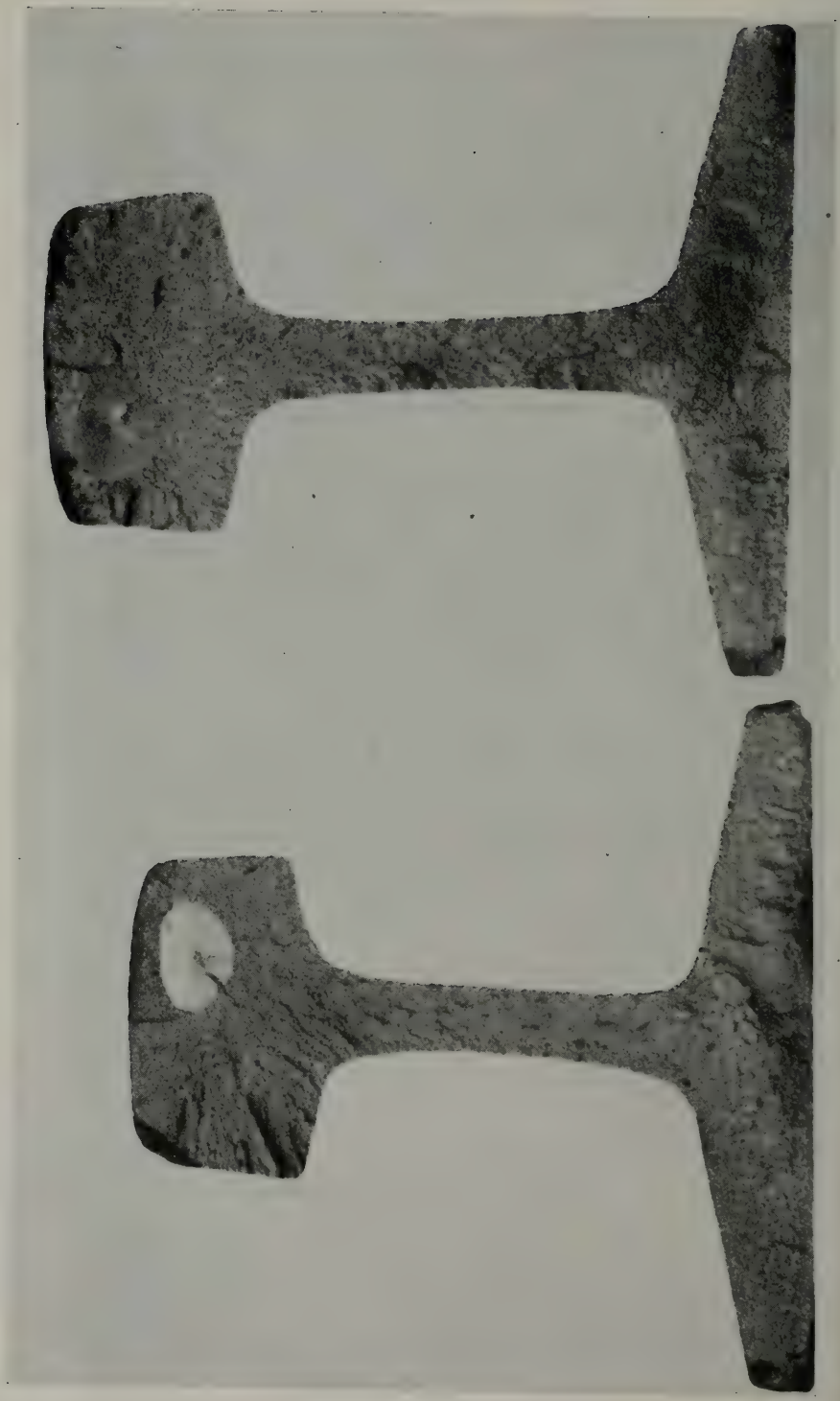
NOTE:-
18' Drop

Sheet No. 2800

PLATE 2215.

TRANSVERSE FISSURES DISCLOSED BY DROP TEST ON RAIL T. D. No. 564.

Transverse Fissures Disclosed by Drop Test on Rail T. D. No. 564.



TRANSVERSE FISSURES DISCLOSED BY DROP TEST ON RAIL T. D. No. 564.

PLATE 2218.

TRANSVERSE FISSURES DISCLOSED BY DROP TEST ON RAIL T. D. No. 564.

Sheet No. 2801.

BRINELL HARDNESS TEST ON HEAD OF RAIL.

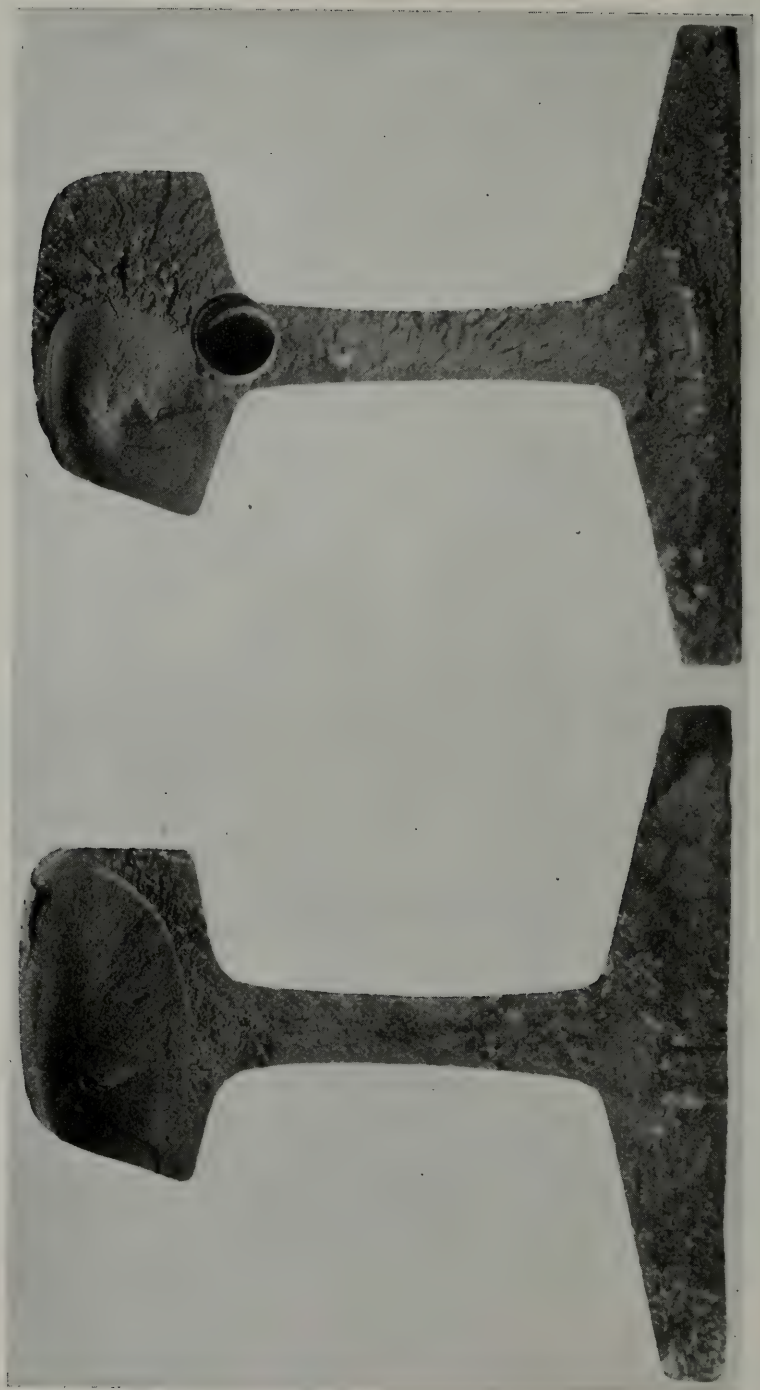
Load, 5,000 Kilograms.

No.	Hardness Numbers								Avg Over All
	On Tread				On Side				
	1	2	3	Avg.	1	2	3	Avg.	
564 Old—1	249	254	261	254.6	246	254	251	250.3	252.4
564 Old—2	256	269	269	264.6	265	256	256	259 0	261.8
565 New—1	220	230	235	228.0	244	246	240	243.3	235.6
565 New—2	220	225	225	223.3	244	246	238	242.6	232 9

ORIGINAL FRACTURES IN RAILS REMOVED FROM TRACK NEAR COLONIA SHOWING TRANSVERSE FISSURES.

ORIGINAL FRACTURES IN RAILS REMOVED FROM TRACK NEAR COLONIA SHOWING TRANSVERSE FISSURES.

ORIGINAL FRACTURES FROM RAILS REMOVED FROM TRACK NEAR COLONIA AND OHIO CONNECTING BRIDGE SHOWING TRANSVERSE FISSURES.



RAILS REMOVED FROM OHIO CONNECTING BRIDGE OF FAILURE DUE TO TRANSVERSE FISSURES.

Chemical Analysis" the first figures are for the "head," the second for the "neck" and the third for the "corner of base." See A, B and C of diagram in Sheet No. 2.

T. D. No.	Tensile Tests				Drop Test	Chemical Analysis										Brinell
	Elastic Limit	Ultimate	Elong. % in 2 in.	Reduc. of Area	Ac. Ft. Lb. 1 x 1 in.	C		Mn		P		Si		S		Hardness
*401	65900	141030	9.5	14.72	750	.91 .90	.87	.77 .77	.77	.014 .014	.016	.073 .066	.075	.021 .021	.022	278
*624	75760	96430	1.	1.2	500	.92 .92	.93	.75 .74	.75	.012 .015	.015	.089 .085	.085	.025 .027	.026	277
*630	64400	132550	9.	13.5	750	.84 .83	.83	.84 .82	.81	.028 .023	.024	.174 .179	.165	.030 .030	.027	280
*555	60720	115660	5.5	5.9	250	.79 .78	.80	.57 .58	.58	.028 .026	.030	.170 .160	.158	.027 .024	030	244
*556	89230	124040	2.	1.7	250	.93 .92	.87	1.43 1.41	1.48	.048 .053	.047	.160 .165	.160	.021 .020	.017	333
*557	91330	112250	1.	1.5	250	.93 .92	.87	1.38 1.39	1.46	.051 .052	.050	.152 .174	.141	.024 .023	.019	320
*558	62100	130350	7.	8.6	6750	.80 .82	.76	.68 .70	.68	.031 .034	.026	.160 .160	.155	.024 .023	.023	265
*559	57920	117970	5.5	6.1	250	.81 .79	.81	.62 .62	.62	.030 .028	.030	.177 .169	.169	.023 .023	.026	262
*560	56930	111560	6.5	10.4	250	.77 .78	.80	.56 .57	.57	.037 .029	.034	.174 .169	.174	.023 .023	.025	254
*561	60390	116850	4.5	6.05	12750	.79 .80	.75	.62 .62	.61	.039 .039	.030	.165 .169	.165	.021 .021	.019	261
562	54690	109930	17.	24.8	24000	.68 .66	.63	59 .59	.58	.041 .026	.025	.113 .122	.122	.023 .020	.020	219
563	66060	111860	2.	3.1	1250	.83 .81	.78	.73 .73	.73	.037 .035	.034	.160 .160	.160	.023 .022	.017	278
697	84870	118200	2.	1.9	1000	.86 .85	.86	.89 .89	.88	.027 .026	.026	.183 .179	.179	.033 .032	.031	318

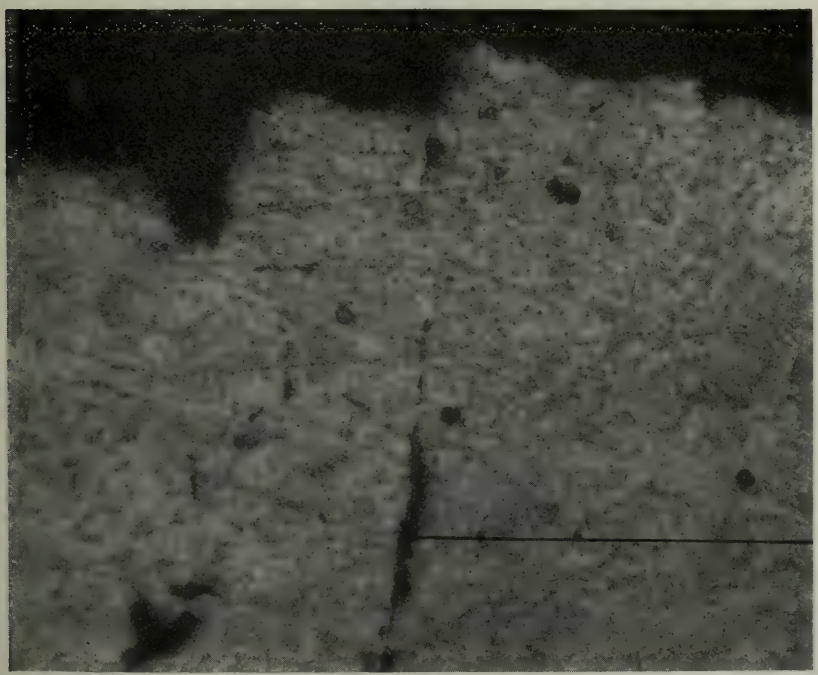
Note—*Transverse fissures found in Rail.

PHYSICAL AND CHEMICAL TESTS OF RAILS.

T. D. No	Tensile Tests				Drop Test	Chemical Analysis					Brinell
	Elastic Limit	Ultimate	Elong. % in 2 in.	Reduc. of Area	Ac. Ft. Lb. 1 x 1 in.	C	Mn	P	Si	S	Hardness
*564	60050	101950	3.	2.6	250	.80 .82 .79	.60 .60 60	.029 .032 .025	.160 .165 .155	.022 .024 .022	261
686	58780	115150	15.	15.3	23250	.70 .69 .70	.63 .63 .64	.039 .036 .037	.108 .103 .118	.034 .029 .035	236
687	82380	151850	8.	11.5	5750	.84 .81 .83	.84 .85 .86	.031 .031 .031	.183 .174 .179	.032 .032 .033	306
688	88050	154400	8.	12.0	9000	.84 .81 .83	.87 .86 .87	.030 .028 .028	.183 .183 .183	.034 .032 .031	317
689	86770	154350	7.	7.7	14250	.85 .82 .85	.87 .86 .87	.031 .027 .029	183 .174 .183	.032 .033 .032	301
690	86510	131600	2.	1.5	500	.85 .85 .87	.85 .88 .88	.030 .027 .028	.188 .183 .179	.036 .037 .043	299
691	82290	147200	5.	6.1	1750	.83 80 .84	.87 .86 .87	.028 .027 .028	.179 .183 .179	.036 .032 .035	300
692	79080	154420	8.	12.6	14250	.84 .79 .83	.87 .86 .87	.028 .026 .030	.179 .165 .165	.029 .026 .033	318
693	85020	118400	3.	1.9	1750	.87 .87 .87	.89 .88 .89	.032 .030 .027	.165 .169 .179	.038 .032 .036	313
694	78930	150600	8.	14.8	4500	.83 .83 .83	.85 .86 .87	.030 .030 .030	.169 .174 .183	.030 .030 .034	313
695	77550	148000	8.	11.8	3750	.82 .79 .80	.87 .86 .87	.028 .026 .027	.174 .165 .174	.030 .027 .035	307
696	87920	152250	8.	11.0	6000	.84 .80 .83	.85 .85 .85	.030 .027 .035	.174 .165 .165	.030 .028 .031	315

Note—*Transverse fissures found in Rail.

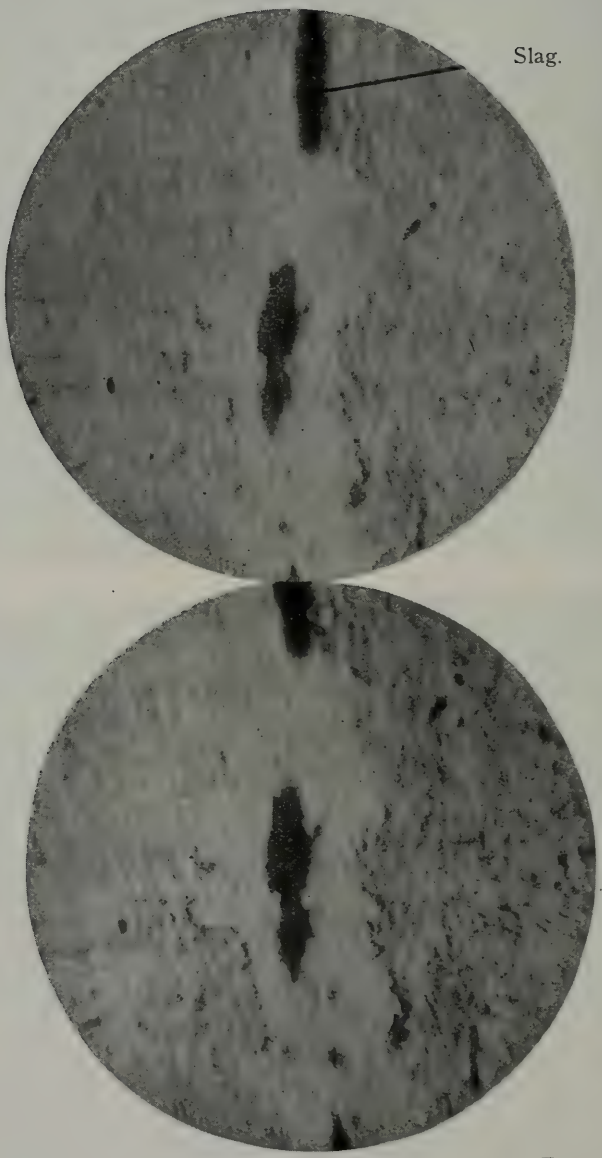
Slag.



Slag.

ETCHED WITH SODIUM PICRATE—MAGNIFICATION 100 DIAMETERS.

SHEET No. 2806.

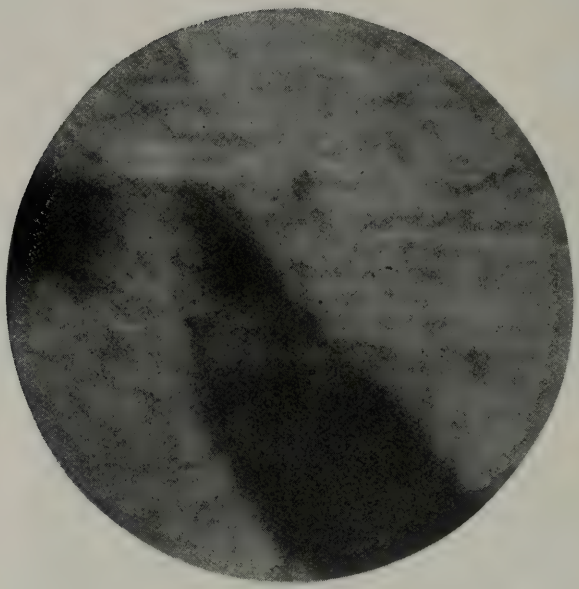


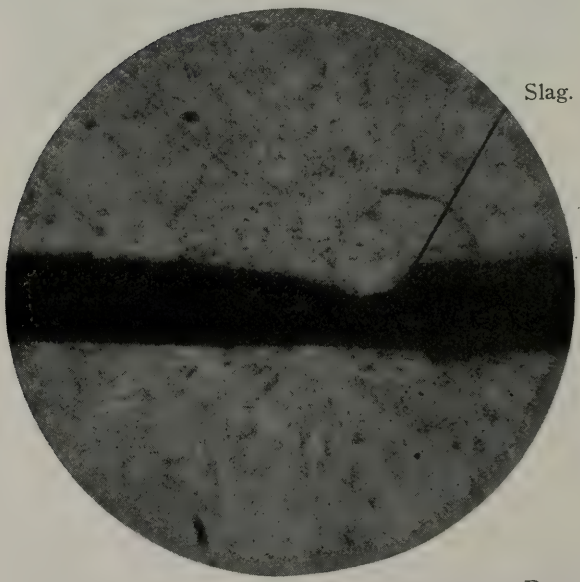
ETCHED WITH SODIUM PICRATE—MAGNIFICATION 1,000 DIAMETERS.

SHEET No. 2806-a.

ETCHED WITH SODIUM PICRATE—MAGNIFICATION 1,000 DIAMETERS.

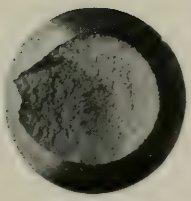
SHEET No. 2807.





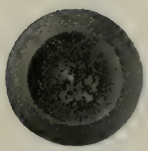
ETCHED WITH SODIUM PICRATE—MAGNIFICATION 1,000 DIAMETERS.

PLATE 2297.



Etched with Sodium Picrate—Magnification 1,000 Diameters.

PLATE 2298.



Transverse Fissure in Tensile Test Piece of Rail T. D. No. 694.
Detail Fracture Produced in Specimen Tested in Revolution Machine Under Alternating Stresses.

PHOTOGRAPHS SHOWING COMPARISONS BETWEEN DETAIL FRACTURE BEGINNING ON THE OUTSIDE AND THE TRANSVERSE FISSURE BEGINNING ON THE INIDE. NOTE THE RADIAL RINGS IN BOTH CASES.

Sheet No. 2854.

NINETEEN RAILS WITH TRANSVERSE FISSURES.

All Open-Hearth.
All showed large grains in micro-photographs.
All showed very satisfactory light etchings.
All showed very satisfactory deep etchings.
All showed a granular fracture except two; one had fine-grained fracture and one a "granular and silky" fracture.
All were only very slightly segregated—ten negatively, seven positively and two none at all.
All showed a fair regularity in hardness.

	Minimum	Average	Maximum
Hardness	244	280	333
Elastic Limit	57,000	69,000	93,000
Ultimate Strength	96,000	120,000	141,000
Elongation	1	5	10
Reduction of Area	1	6	15
Carbon	.78	.84	.93
Manganese	.60	.76	1.44
Phosphorus	.014	.028	.051
Silicon	.055	.141	.173
Sulphur	.019	.026	.035

Bethlehem Steel Company.....13 Rails.
Pennsylvania Steel Company..... 4 Rails.
Lackawanna Steel Company..... 1 Rail.
Cambria Steel Company..... 1 Rail.

T. D. No.	Tensile Tests				Drop Test	Chemical Analysis							Brinell
	Elastic Limit	Ultimate	Elong. in 8 in.	Red.	Ac.Ft.Lb. 1 x 1 in.	C	Mn	P	Si	S	Ni	Cr	Hardenss
395	62200	121800	5	4.5	14250	.84 .78 .81	.72 .70 .72	.014 .014 .014	.056 .056 .054	.030 .025 .029	P. S. Co. 3-09	.....	265
401	65900	141000	10	14.7	750	.91 .87 .90	.77 .77 .77	.014 .016 .014	.073 .075 .066	.021 .022 .021	Beth. 11-09 16740	.....	278
402	65500	120950	4	5.6	1750	.92 .93 .94	.76 .76 .77	.019 .018 .017	.073 .069 .066	.025 .026 .025	Beth. 11-09 16740	.....	293
452	84200	112700	4	6.1	.....	.83 .84 .84	.87 .90 .89	.025 .024 .026	.112 .170 .167	.032 .030 .030	1.00 .97 1.01	.26 P. S. .27 .26 Co. 16685 11-10	308
453	93150	124700	1	1.0	2750	.87 .85 .87	.88 .88 .89	.025 .024 .024	.172 .172 .167	.034 .035 .034	1.01 .99 1.00	.27 P. S. .26 .27 Co. 16686 11-10	330
454	84600	136850	1	4.6	1750	.88 .84 .86	.87 .90 .90	.029 .028 .025	.165 .167 .170	.034 .036 .035	1.03 .97 1.00	.27 P. S. .27 .27 Co. 16686 11-10	331
497	68500	114650	3	3.6	2750	.84 .83 .84	.66 .67 .67	.030 .031 .029	.160 .160 .165	.026 .024 .025	Beth. 2-10 16246	.....	278
542	59400	121500	10	12.2	250	.81 .83 .77	.69 .68 .68	.029 .030 .038	.146 .141 .141	.031 .033 .030	Beth. 1910 14304	.....	261
549	65700	123750	10	11.4	15000	.81 .81 .83	.66 .67 .66	.021 .020 .022	.108 .111 .113	.031 .031 .032	Cambria 5-09 5517	.....	263
555	60700	115650	6	5.9	250	.79 .80 .78	.57 .58 .58	.028 .030 .026	.170 .158 .160	.027 .030 .024	Beth. 11-10	.....	244
556	Split 89200	Head 124050	6	1.7	250	.93 .87 .92	1.43 1.48 1.41	.048 .047 .053	.160 .160 .165	.021 .017 .020	Beth. 11-10	.....	333

Note:—*Presence of Transverse Fissure in doubt.

Sheet No. 2856. RAILS SHOWING TRANSVERSE FISSURE.

T. D. No.	Tensile Tests				Drop Test	Chemical Analysis						Brinell
	Elastic Limit	Ultimate	Elong. % in in.	Reduc. of Area	Ac. Ft. Lb. 1 x 1 in.	C	Mn	P	Si	S	Ni	B
	Split Head—Soft Steel Streak in Base					1.38	051	.152	.024		Beth.	
*557	91350	112250	1	1.5	250	.93 .87 .92	1.46 1.39	.050 .052	.141 .174	.019 .023	11–10	320
558	62100	130350	7	8.6	6750	.80 .76 .82	.68 .68 .70	.031 .026 .034	.160 .155 .160	.024 .023 .023	Beth. 11–10	265
559	57900	118000	6	6.1	250	.81 .81 .79	.62 .62 .62	.030 .030 .028	.177 .169 .169	.023 .025 .023	Beth. 11–10	262
560	57000	111550	7	10.4	250	.77 .80 .78	.56 .57 .57	.037 .034 .029	.174 .174 .169	.023 .025 .022	Beth. 11–10	254
561	60400	116850	5	6.1	12750	.79 .75 .80	.62 .61 .62	.039 .030 .039	.165 .165 .169	.031 .019 .021	Beth. 11–10	261
	Hor. long. crack in head											
564	60050	101950	3	2.6	250	.80 .82 79	.60 .60 60	.039 .032 .025	.160 .165 .155	.022 .024 .022	Beth. 11–10	261
624	75750	96450	1	1.2	Trans. Fis. 500	.92 .93 .92	.75 .75 .74	.012 .015 .015	.089 .085 .085	.025 .026 .027	Beth. 11–10	277
630	64400	132550	9	13.5	Trans. Fis. 750	.84 .83 .83	.84 .81 .82	.028 .024 .023	.174 .165 .179	.030 .027 .030	L. S. Co. 1909 4319	280

Note:—*Presence of Transverse Fissure in doubt.

Appendix J.

METHOD OF PRODUCING SOUND INGOTS.

Introduction by W. C. CUSHING, Chief Engineer Maintenance of Way, South West System, Pennsylvania Lines West.

"In general terms, *welding* may be described as the crystallizing into union of two solid metallic surfaces when they are brought together under suitable conditions. That such is the case is proved by microscopic examination, for on polishing and etching sections of the united metals, the crystals along the junction are found to be common to each of the original pieces of metal. In perfect welding, there is no visible joint, for the line or plane of junction is occupied by crystals, portions of which belong to one piece of metal and portions of the same crystals to the other. When the boundaries of the crystals are coincident with the juxtaposed plane surfaces, it is evidence of non-welding, which is equivalent to saying that unless the crystals become common to the two pieces there is no welding. . . .

"The conditions necessary for the welding of two metallic surfaces of iron or steel are:

"(1) The surfaces must be clean and free from any foreign infusible substance, such as oxide of iron, slag, lime, etc.

"(2) The metallic surfaces must be in actual contact."

The above quotation is taken from "Notes on the Welding Up of Blow Holes and Cavities in Steel Ingots," by J. E. Stead, D. Met., F.R.S. (then Vice-President of the Iron and Steel Institute), in "Journal of the Iron and Steel Institute," No. 1 for 1911.

Dr. Stead then describes several series of experiments which "prove conclusively that when two metallic surfaces quite free from oxide or any foreign matter such as slag, sulphide of manganese, alumina, etc., are brought together and are forged under the conditions given (in his tests) at temperatures about 1100° C., they do weld up completely."

In connection with the description of his experiments, Dr. Stead explains the difference between honeycombed ingots and piped ingots, and in speaking of blowholes he quotes Professor Howe, who has given the subject a great deal of study in the United States.

"It is well known . . . . that if the steel has been in contact with more or less ferruginous slag previous to being poured, the metal is more

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or less highly charged with oxide of iron; and that if no metal or metalloid —such as aluminum, silicon or titanium—capable of reducing this oxide, is added to the liquid steel on cooling down . . . a chemical reaction is brought about by fall of temperature, or by passage from the liquid to the solid state."

The examination of the fractured and cut surfaces of honeycombed ingots, made by Dr. Stead, has yielded proof that the honeycombed cavities are lined with metal rich in sulphur and phosphorus.

Nevertheless, he has proved "that welding up of the blowhole cavities in ordinary practice, unless the cavities themselves contain foreign matter, is, as a rule, complete and perfect, has been proved by microscopic examination of a large number of specimens at the points where blowhole segregations indicated that small cavities had originally existed."

This is his explanation of piping in ingots:

"Piping in steel ingots is always coincident with the complete or partial absence of blowholes, or evolution of gas from the steel when it is in the plastic state. When gases are liberated in sufficient quantity, piping is impossible.

"All steel in cooling towards the point of solidification contracts, and as solidification proceeds from the cold sides of the moulds in an inward direction, and when no gases are evolved in the steel as it passes through the plastic state, the liquid contracts and sinks down the center, leaving a pipe or cavity, but if gas is evolved it causes the whole mass of plastic steel to expand, which more or less balances the contraction of the metal still remaining liquid, with the result that no pipe or very little pipe can form, or the volume of plastic steel and the gases together may increase and cause the metal to froth over the top of the mould. . . . .

"In cases where the cavities consist of central continuous pipes, long experience has shown that finished rails and forgings made from piped steel ingots are almost invariably unsound in the parts where the pipe existed, and that welding together of the walls of the pipe cannot be depended upon, and, as a result, it is usual to reject the parts of ingots in which there is a central cavity when the object is to obtain perfectly sound finished material."

Nevertheless, Dr. Stead has proved that it is possible to weld together the surfaces of a closed up pipe. When the conditions of temperature are right and no foreign material is present, he has "strong ground for the presumption, however, that if the faces of a closed up pipe are crystallized or welded together at several separate points only, and not completely, forging at relatively low temperatures, say at 750° or 850° C., tends to cause disruption of the primarily united portions, particularly in cases where the steel is rolled to small sections. The reason for this hypothesis is that juxtaposed faces probably do not always flow evenly when the steel is being forged or rolled, and that if one face flows in advance of the other, disruption of the parts united occurs, due to shearing effect.

"It is well known that even in quite sound material it is possible to produce internal disruption by a special rolling process, and if it can be

effected in sound steel, how much more readily must it occur in initially imperfectly welded material."

In the case of steel ingots, "the upper ends of the pipes are open to the gases of the heating furnace, and the walls of the cavities become coated with oxide scale, which effectually prevents the metallic surfaces from coming into contact." This fact makes it very doubtful whether or not pipe cavities in steel ingots can be readily welded. "It is a fact observed by Dr. Stead that the surfaces of the walls of the pipes in commercial ingots containing .06 per cent. or more sulphur are rich in manganese sulphide, and this must interfere with the perfect contact of the metallic surfaces, for from a practical point of view, manganese sulphide is equivalent to scoria or slag."

The final quotation from Dr. Stead's paper which the writer will give leads up to the real subject of this communication, and it is as follows:

"It is obvious that if the uppermost layers of steel in an ingot could be kept fluid across the whole area or section till the metal from the bottom to an inch below the surface had solidified, there would be no pipe, and if the steel were of a non-gaseous character there would be no blow holes."

The writer has had these problems in mind for a long time, and finally turned to Sir Robert Hadfield, F.R.S., Past-President of the Iron and Steel Institute of Great Britain, and a manufacturer of famous steel at the Hecla Works in Sheffield, England, on account of his having been the author of many valuable works containing original researches in the problems of steel making, and he met with such a hearty and cordial response from Sir Robert that it resulted in his presentation of the two papers, "Method of Producing Sound Ingots," and "On a New Method of Revealing Segregation in Steel Ingots," which he had just written for the Iron and Steel Institute, to be read at its meeting on September 30th, 1912, and his cabled permission to issue them in the Bulletin of the American Railway Engineering Association.

The subjects of segregation, blowholes and piping are well explained by Sir Robert, and he has clearly shown that in tests and in practice it is possible to overcome those defects, so that "in many cases no less than 92 per cent. of the fluid steel in the mould is made utilizable, and this at small expense. . . . It is estimated that on a large output the saving by this method is about 8s to 12s per ton."

This is timely and cheerful news, as it shows that improvements in steel manufacture have already been made in the very direction in which we are most concerned, and that those improvements have resulted in a saving of money to the manufacturer himself. After reading Sir Robert Hadfield's papers, there is no ground whatever to stand upon for demanding a fixed percentage of discard from the tops of ingots used for the manufacture of rails, such, for instance, as 25 per cent. The proper amount of discard is the amount of unsound metal, whether it be 8 per cent. or 50 per cent., and we believe the method of our specifications to be the proper one for bringing this about as nearly as possible.

Sir Robert has read with interest Mr. Wickhorst's report on "Pipeless Ingots" in Appendix "D" (first printed in Bulletin No. 147, July, 1912), and makes the following comments on the difference between the method of the Standard Steel Works Company and of the method described in his papers:

"I have carefully read the description of these experiments. Whilst the method quoted represents a procedure better than current practice in rail ingots, I do not agree with the addition of carbon in the form of graphite, that is, added in this particular manner, as the steel on the upper surface of the ingot would be very liable to become contaminated, and help to increase segregation troubles.

"It is for this reason my process differs from all others to my knowledge, namely, in having an insulating layer of fluid slag interposing between the fluid steel of the ingot and the source of heat from above, which helps to feed the metal as it shrinks.

"My method differs therefore in this respect, and, I think, is much superior. Moreover the continuation of the heating process enables the feeding of the ingot from the top to take place naturally, and as it should occur.

"The method described of the Standard Works would be liable to very serious irregularity; by my method *every ingot can be made the same.*"

METHOD OF PRODUCING SOUND INGOTS.

By Sir Robert Hadfield, F. R. S. (Past-President Iron and Steel Institute).

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INTRODUCTION.

Owing to the trouble which has been experienced by railroads, especially in countries where low temperatures prevail in winter time, it has become a necessity to look more carefully into the matter of obtaining sound rails, free from piping, blowholes and other defects. This in its turn means that the ingots from which the rails are made should also be quite sound and free from piping, segregation or other defects. The improved method is applicable to ingots for other purposes, whether of the ordinary square, oblong, round, or other form.

In view of the rapid production of the large quantities of steel ingots required for a modern rail mill, whilst the production of a "sound" ingot may not be so easy as it seems at first sight, yet attention may be drawn to the subject with advantage. Perhaps the question has not received as full investigation as should have been the case. Moreover, apart from the question of soundness, the waste experienced under the present condition of manufacture is very considerable. Therefore, any system which shows how to reduce the loss by waste and scrap is one of more than ordinary interest to the steel maker, as this means not only a better product, but a more economical one. Although some of the information now given has appeared elsewhere, it has been suggested to the author of this paper that the questions dealt with, being of considerable importance, might well be brought before the Institute.

The question of producing sound steel is as important a factor in meeting the requirements of the times as ever it was. By sound steel is generally meant material free from (*a*) segregation, (*b*) blowholes and (*c*) piping. Unless these requisites are fulfilled, trouble and breakdown of the rolled or forged material produced from the ingots may occur in some stage of its history. Fortunately, as a rule, the remedy which obviates or overcomes any one of the difficulties tends to improve all. For example, steel which is sound and free from blowholes is less liable to segregation or intermingled slag, and the ingots made therefrom, if properly fed, will have the defects under (*c*), that is, piping, largely reduced.

Many simple devices as well as complicated arrangements have been suggested and tried to overcome the difficulties in question—as, for example, fluid compression from the top, also from the bottom; feeding

the settling by gas-generated heat; compressing or squeezing from the sides, and many other devices which have given more or less satisfactory results. There are, however, some disadvantages in these systems; amongst others, the expense of application owing to the heavy cost of apparatus.

For some years the author has been working at methods which appear to him to be simple yet efficient. In view of the great importance of obtaining sound material, a general description of these methods may be of interest and not out of place; in fact, the author has been asked to bring the results before the Institute. A system of this kind, with suitable modifications, is applicable to the manufacture of sound ingots from which to make rails and other products. The terrible results of railroad disasters, such as those on the Lehigh Valley Railroad in America last August, and the New York Central Railroad in March of this year, show the importance of obtaining sound material in the ingots from which the rails are to be rolled.

To show that these remarks with regard to the necessity of improving the methods of making ingots for rails and other purposes are well founded, attention is drawn to Plates XII. and XIII. In these plates are shown several specimens of the ingots, blooms and rails investigated by the official American Committee on Manufactures and shown in the "Report of the Tests of Metals and Other Materials for Industrial Purposes" (1909) made by the American Government Testing Department at Watertown Arsenal, Massachusetts. This excellent report comprises five parts in three volumes and many hundreds of photographs and tests. The striking facts there shown fully confirm the great importance and desirability of obtaining better and sounder material in rail ingots, both as regards reducing blowholes, also avoiding piping and segregation.

These plates (XII and XIII) show 17-inch ingots, blooms and partly rolled rails and finished rails of 75 pounds section which have been sectioned and etched. The report above mentioned does not state that these are in any way special. If, therefore, current practice is represented, it will be seen that when starting with unsound ingots it is not possible to obtain sound billets or rails.

The serious nature of the question is fully shown by the facts set forth in "The Report of Accident on the Line of the Lehigh Valley Railroad, Near Manchester, New York, August 25, 1911," by the Interstate Commerce Commission. The rail in question, which broke with such disastrous effect, is shown to have been very defective. The author will not attempt to deal with this in the present paper, but would refer the reader to this valuable report.

However, from the above instances alone, it will be seen how important is the production of ingots of sound steel, whatever may be the temper or hardness of the steel; that is, mild, medium, or hard or special steels. This point has long been recognized in Sheffield in the manufacture of special steels, both for small and large ingots of crucible cast

steel, in which the upper or top portion is provided with a fire-clay top, or "dozzler;" in other words, the ingot is "dozzled."

The ingots dealt with in the present paper are chiefly those of medium size, such as used for rail production. They may be termed neither small nor large; that is, they are medium sizes and weights, varying from say ½ a ton to say 2½ or 3 tons each, and from say 8 inches or 10 inches to 20 inches or 24 inches square.

The chief object of this paper is to deal with this special method, as full descriptions of various other processes have already appeared in technical literature—that is, relating to the Whitworth, Harmet, Riemer, Illingworth, Robinson and other processes.

In confirmation of the author's views as to the desirability of obtaining absolutely sound steel, free from blowholes, piping and segregation, he quotes the following from Mr. B. Talbot's excellent paper, "Segregation in Steel Ingots."* At the end of this paper Mr. Talbot says:

"In my opinion it would be well worth while for other investigators interested in the manufacture of higher carbon steel, such as for rail, tyre and similar purposes, to follow up these results with a view to proving whether a more uniform and regular steel is not thereby obtained, a result well worth the few pence per ton the aluminum would cost. Perhaps the chief result to be looked for would be the decreased amount of crop end that it would be necessary to cut off from the top of the ingot, due to the greater solidity of the top and the lessened amount of segregation in this top part of the ingot. This alone would undoubtedly pay for the cost of the aluminum added, without considering the more regular quality of the finished product as a whole."

This is exactly the point so strongly insisted upon by the author of this paper, namely, that with piping steel the quality is raised as regards greater soundness and less segregation. To get these full advantages it is necessary to have a method of properly feeding or filling up the settling which would otherwise be produced by steel having such piping tendencies.

The author believes the method now described satisfactorily meets these requirements, both as regards improving the quality of the material and also cheapening production, by making an ingot which by being sound offers less waste.

Amongst others, Professor Henry M. Howe has dealt with this question of segregation and piping in some interesting papers, including those on "Piping and Segregation in Steel Ingots"† and "The Influence of the Conditions of Casting on Piping and Segregation as shown by means of Wax Ingots."‡ The author will not go into these in detail, but would call attention to the interesting results obtained by Professor Howe with regard to studying the condition of piping and segregation occurring in wax ingots, made with a view to show that in the cooling of fluid steel poured into ingot molds their behavior is similar.

*Journal of the Iron and Steel Institute, 1905, No. II., pp. 204, etc.
†Preliminary paper read at our London meeting, July, 1906.
‡Read at the New York meeting of the American Institute of Mining Engineers, April, 1907.

At the Hecla Works, Sheffield, of the author's firm, large quantities of special steels are made, in which it is essential to have perfectly sound material, free from the segregations previously referred to (*a*), (*b*) and (*c*). The methods now described have enabled the desired object to be fulfilled both cheaply and efficiently. Moreover, it has the important advantage of enabling not only soundness to be obtained, but also a much larger percentage of the ingot to be safely used. As will be seen from the results of the experiments described, in many cases no less than 92 per cent. of the fluid steel in the mold is made utilizable, and this at small expense.

Granted in the first instance, therefore, that we are dealing with sound piping or settling steel, which is easily obtainable by ordinary care in manufacture, there seems to be no reason why the ingots should not be sound, free from blowholes, piping and segregation. This being so,

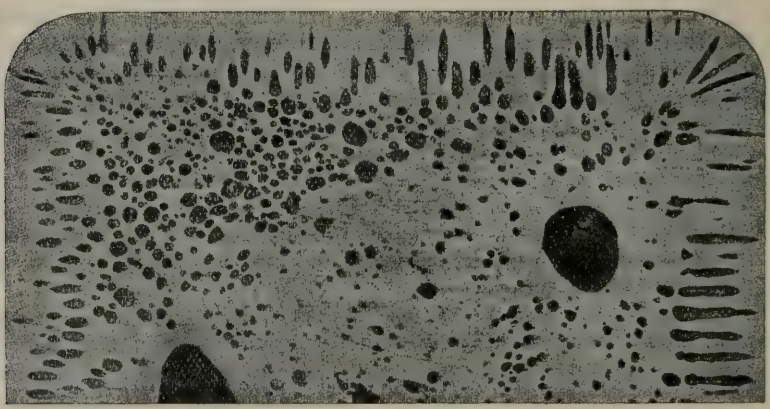

FIG. 1.—INGOT 2A. HALF INGOT, CROSS-SECTION SLICE, 2A1. SMOOTH FINISHED, UNETCHED. LOCATION OF SURFACE FROM TOP OF INGOT 1.4 IN.; 4 PER CENT. BY DISTANCE; 3.7 PER CENT. BY VOLUME. ABOUT ONE-SIXTH ACTUAL SIZE.

Ingot for rails. Illustration taken from the "Report of the Tests of Metals, 1909," made by the American Government Testing Department at Watertown Arsenal, Mass.

rails or other articles rolled from such ingots should be of the highest grade. It is true that large quantities of rails as now made are of excellent quality, but it is just the "tenth" case which it is important to improve. It is the bad heat here and there, the bad ingot now and then, which give the fatal rail which in service fails, involving catastrophe and all the troubles consequent upon such disasters. The methods described in this paper appear to offer a solution of this serious problem.

As an illustration of the unsoundness sometimes met with, Fig. 1 ("Ingot 2A") shows a specimen of an unsound ingot of a nature familiar to us all. The author thinks that no amount of careful treatment can

make a rolled or forged article prepared from such an ingot properly sound.

Plate I shows the upper portion of four small ingots, each about 4 in. square and 30 in. in length, which were made to illustrate and test the question of soundness and piping.

No. 1 shows the steel as poured into the mold without any solidifying addition. This probably represents much current practice, for the

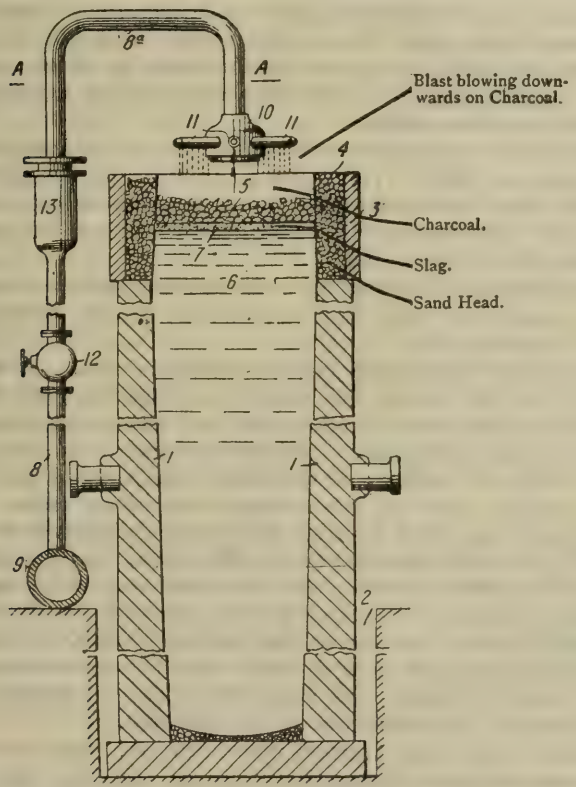

FIG. 2.—APPARATUS EMPLOYED IN PRODUCING SOUND INGOTS, SHOWING THE BLAST BLOWING DOWNWARDS ON THE CHARCOAL.

reason that at present methods to take away the piping are not used, therefore piping steel is avoided. The author has been told by a rail maker abroad that he required steel which neither rose in the molds nor piped, a most difficult matter to accomplish in practice, besides theoretically incorrect.

No. 2 shows the same steel as used in No. 1 quietened by the addition of 0.036 per cent. of aluminum. This is still not altogether sound.

No. 3; to this was added more aluminum, namely, 0.09 per cent. The steel here is quite sound, but pipes deeply.

The ingot maker appears, therefore, to be in a dilemma. If he makes his steel so that it will not settle, then it is unsound, like No. 1. If he makes it sounder, like No. 2, this pipes and so is still not satisfactory, and there is much waste. No. 3 is quite sound, but the piping is almost as bad an evil as the unsoundness shown in No. 1.

To overcome this difficulty, the methods described in this paper seem to be those best suited to give the desideratum of sound material from piping steel. Ingot No. 4 represents the same steel of the sound type used for ingot No. 3, but furnished with the proper feeding top referred to in this paper. It will be noticed that the ingot is not only sound but free from piping.

The object in many steel works seems to be to try and avoid a steel which pipes or settles. This really arises from the natural desire to avoid the trouble and expense of making preparations for dealing with piping steel. The desideratum in the author's opinion is "piping steel" which should be properly fed.

The following is a description of the author's method of casting steel ingots, castings, etc., which insures soundness, freedom from piping and absence of segregation:

The method of carrying out the process is shown in Fig. 2 and Plate II. As will be seen, this consists in heating the fluid steel in the upper part of the ingot or other mold and maintaining it in a liquid condition by the combustion, in contact therewith, or in close proximity thereto, during the cooling and shrinkage of the metal in the lower part of the mold, of solid fuel—for example, charcoal—by means of a blast of compressed air which is caused to impinge on the fuel while this is directly or indirectly supported by the metal below; and the interposition of a layer of fusible material, such as cupola slag, which has little or no injurious action on the metal, between the metal and the fuel. This slag largely prevents radiation of heat, the loss by which is much greater than ordinarily supposed to be the case. Plate III shows the ingots being poured, with the feeding apparatus, blast, etc., in operation. Suitable modifications of the process can also be employed.

In Plate II the upper portion, black and red, shows the charcoal. Then comes the layer of slag about ½ in. in thickness. The pink portion represents the fluid steel in a 15-in. ingot-mold. The sand or other suitable top to provide the feeding head portion is shown in gray, inserted in the molding-box fixed onto the top of the ingot-mold itself. Whilst the ingots can be cast as at present, that is, large end down, this particular design shows the small end of the ingot downwards. There is no doubt this is the better method, as by the small end forming the bottom portion, cooling takes place more quickly, causing the steel to congeal there and thus reduce the amount of feeding required later on from the upper portion of the mold.

Fig. 3 shows how the same method is applied to ingots with the larger end at the bottom.

The cost of carrying out the method is trifling compared with the large saving effected by reducing loss and waste of material. Moreover, the quality of the product is improved; for example, in making rails produced from such ingots, not only is there less discard, but the material is sounder. During the last few years many thousand tons of ingots have been made by this patented process, which has been found of great advantage.

As a specific example, it may be mentioned that ingots have been made, weighing about 5,000 lbs. each, in which the piping and discard do not amount to more than about 7 per cent. This small loss is not the only advantage, the chief one being that material is obtained which is quite sound and free from hidden pipes or other defects on the whole length of the ingot. The system can be applied equally well to either smaller or larger ingots, for all kinds of purposes, and for ordinary or special steels.

It is estimated that on a large output the saving by this method is from about 8s. to 12s. per ton. Thus, on a large tonnage of hundreds of thousands of tons annually, there would be a very considerable saving each year, as well as obtaining sound ingots free from blowholes, piping and segregation.

In this experiment even the segregation usually noticed was almost entirely absent, only a few inches below the feeding head placed on the top of the ingot. At about 4 in. below the surface of the sinking head the percentages of sulphur and phosphorus were practically the same as in the original steel, namely, about 0.03 per cent. each.

The following is a description of the ingots made from heat No. 9376-2185 steel:

The sand head was 14 inches square where it joined the ingot, tapering to 9 in. square in a length of 16 in. The steel was filled up in the sinking head to a depth of 14 in., the remaining 2 in. of sand head being filled with a layer of ground slag, having a thickness of about 1½ in. The slag was put on the molten steel, then the heating carried out by means of the charcoal and blast in the manner described in the patent specifications. The head was afterwards cut off the ingot, and was found to be free from piping or segregation.

TABLE I.

Total Weight of Ingot.	Weight of Sand Head.	Weight of Sound Ingot.
Cwts. Qrs. Lbs.	Cwts. Qrs. Lbs.	Cwts. Qrs. Lbs.
38 3 0	2 2 10	36 0 18
(4,300 lbs.)	(290 lbs.)	(4,050 lbs.)

This is equal to a waste of about 6.7 per cent.

The steel "fed" well, practically the whole of the molten steel in the head having descended bodily to feed the cooling shrinkage of the ingot.

The head was drilled and analyzed in order to find out if there was segregation. The results are shown in the following table. It will be seen that even "C" is almost normal in its composition, and "D," a little lower down, has practically the same analysis as the bulk of the ingot.

The original analysis in this heat, as shown by the test ingot, was:

	Per Cent.
Carbon	0.50
Silicon	0.16
Sulphur	0.033
Phosphorus	0.037
Manganese	0.80

TABLE II.

Position of Test-piece below Surface of Feeding Head.	Analysis.		
	Carbon per Cent.	Sulphur per Cent.	Phosphorus per Cent.
"A," 1 inch below	1·41	0·175	0·135
"B," 2 inches below	1·20	0·12	0·10
"C," 3½ inches below	0·59	0·041	0·041
"D," where ingot itself commences	0·50	0·033	0·037

This ingot with the sinking head described is a still further advance in the improvements effected in this matter, the segregation being very slight. It would appear that 93 per cent. of this ingot may be utilized for commercial purposes.

The following further experiments with this method were carried out:

Two heats were made of mild and ordinary steel. In the former the carbon was 0.20 per cent., silicon 0.40 per cent. and manganese 0.60 per cent.; in the latter, carbon 0.45 per cent., silicon 0.50 per cent. and manganese 0.80 per cent. The ingots were prepared in the manner described; that is, sufficient cupola or similar slag was placed upon the upper portion of the molten steel in the ingot-mold, then charcoal and blast applied by means of the special blowpipe arrangement shown in Fig. 3. Each ingot was provided with a sand top, placed at the top of its ordinary length of the cast-iron mold. The exact method is shown in Fig. No. 4. The following were the results obtained:

Mild Steel.—Seven ingots were cast from heat X9428-1843 and seven cast from heat X9438-1843. Total weight, 6 tons, 17 cwts., 2 qrs. Forged March 25, 1908.

TABLE III.

	Tons.	Cwts.	Qrs.	Lbs.	Per Cent.
Head scrap	0	8	0	0	6.0
Billet scrap	0	1	2	0	1.0
Forge waste	0	2	2	0	1.8
125 billets	6	5	2	0	91.2
	6	17	2	0	Total waste, 8.8 per cent.

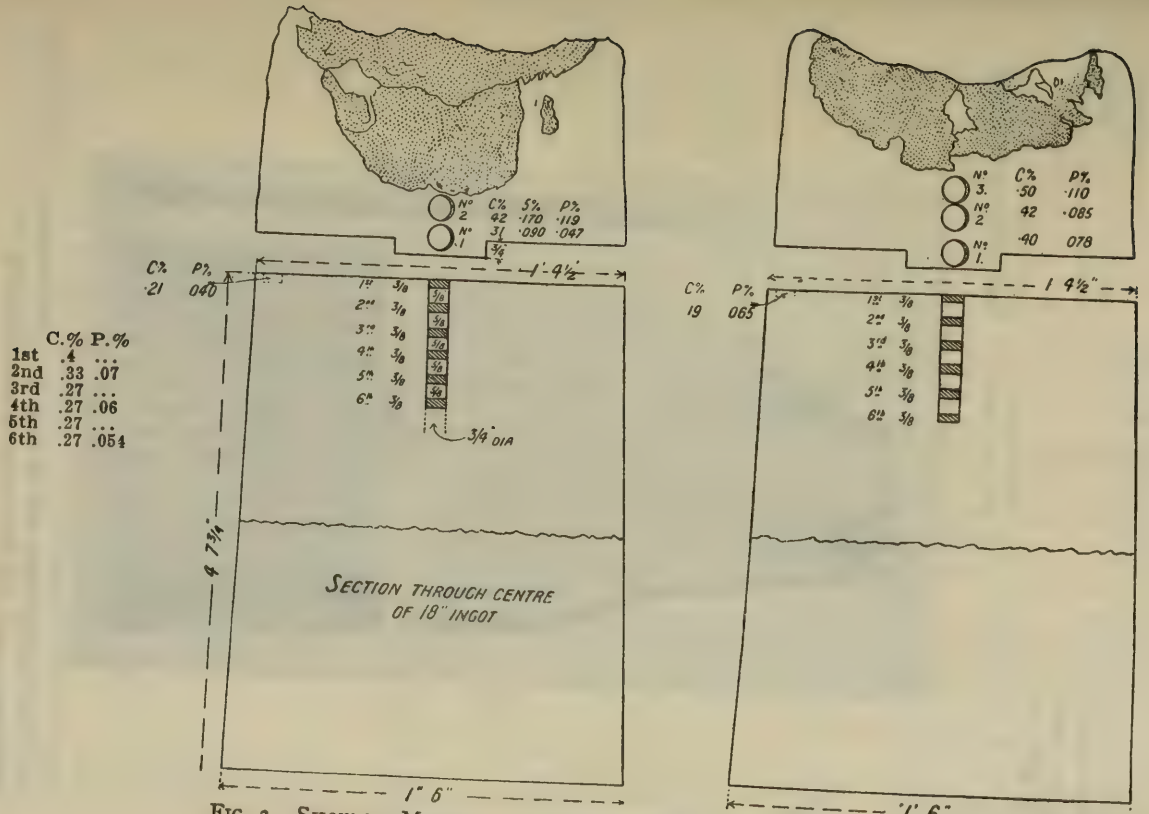

FIG. 3.—SHOWING METHOD AS APPLIED TO INGOTS WITH THE LARGER END AT BOTTOM.

Ordinary Steel.—Seven ingots were cast from heat X9387-6 and seven cast from heat X9396-6. Total weight, 6 tons, 17 cwts. Forged March 24, 1908.

TABLE IV.

	Tons.	Cwts.	Qrs.	Lbs.	Per Cent.
Head scrap	0	7	3	0	5.6
Billet scrap	0	1	0	0	0.7
Forge waste	0	2	0	0	1.6
126 billets	6	6	1	0	92.1
	6	17	0	0	Total waste, 7.9 per cent.

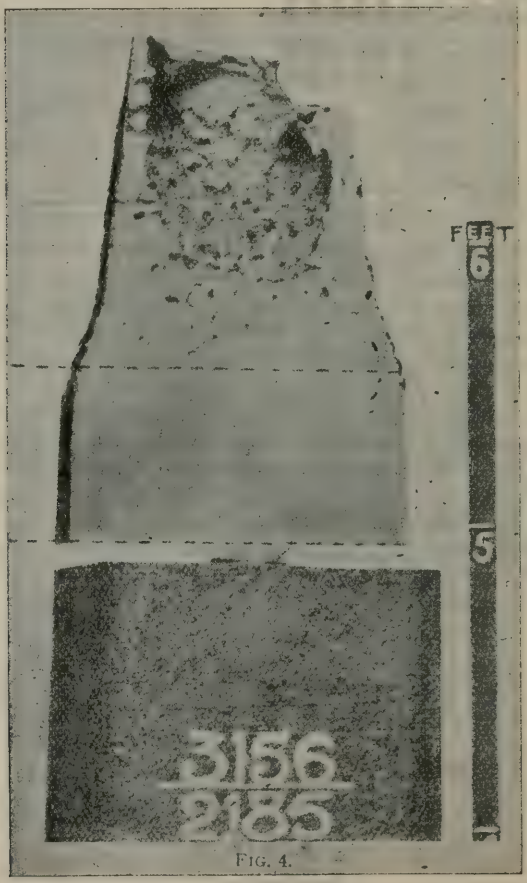

FIG. 4.

These ingots forged well in each case and the billets produced therefrom were sound and satisfactory in other respects.

In the experiments made it was found that, with the exception of 8.8 and 7.9 per cent. waste, respectively, practically the whole of the remaining portion of the ingots represented saleable and serviceable billets. The same results may be obtained with either small or large ingots.

Plate IV shows a 15-in. ingot broken further down to show that the piping has been completely obviated, and that it does not "break out again," as is sometimes noticed when using other methods to avoid the troubles from piping.

A further ingot is shown in Plate V. This ingot was carefully tested for segregation (Nos. 1, 2 and 3 in this diagram), but it will be seen that this gradually disappeared. The next section underneath No. 4 was quite normal composition, namely, carbon 0.52 per cent., silicon 0.11 per cent., sulphur 0.068 per cent., phosphorus 0.053 per cent., manganese 0.79 per cent., which represents the composition of the ordinary small test-piece taken from the ingot.

Plate VI shows two ingots, each weighing about 2,300 lbs. From the results obtained in the finished product great improvement was found over the methods ordinarily practiced, whether as regards saving in waste or improving the quality of the material.

These ingots were heated and rolled into rails in the ordinary manner without any trouble.

Plates VII, VIII and IX represent respectively sulphur prints, polished sections and etched sections of rails rolled from these ingots. The upper portion of the top rail, that is from the part of the ingot immediately under the feeding head, has been carefully etched. Plate X shows a full size polished section of the rail. It will be seen from these illustrations how entirely free from imperfection are rails made by this method.

To bring the whole of the work briefly before the members, the author has prepared Plate No. XI, on which are shown—

(*a*) The head cut off a 15-in. ingot, showing sound fracture and practically no segregation. The head portion represents only 8 per cent. of the total weight of the ingot.

(*b*) The rail rolled from the ingot *a*—
Total length of rail, 64 ft.
Total length of rail free from piping and segregation, 62 ft. 7 in.

(*c*) Rail discard, weighing 24 lbs., from the portion immediately under the machined surface of the head, shown in Fig. (*c*), that is, from the most unfavorable portion. It will be seen that the rail is quite sound.

(*d*) This soundness is further proved by the etched section taken from the top of the rail shown in Fig. (*c*).

Although most of the results shown in this paper relate to ingots cast with the small end at the bottom of the ingot-mold, there is no difficulty in applying the system to ingots cast in the manner generally

practiced; that is, with the larger end at the bottom and the smaller end at the top of the mold.

The 15-in. ingot of the following analysis, shown in Fig. 4, was

	Per Cent.
Carbon	0.48
Silicon	0.12
Sulphur	0.077
Phosphorus	0.047
Manganese	0.74

cast in this manner; this ingot was about 6 ft. in length and about 2 tons in weight. The figure shows the ingot with the upper portion removed.

An 18-in. ingot was also made of mild steel of the following analysis:

	Per Cent.
Carbon	0.20
Silicon	0.04
Sulphur	0.045
Phosphorus	0.04
Manganese	1.30

This is shown in Fig. 3. It will be noticed that in this case the segregation practically ceases at about the third hole below the upper surface of the feeding head.

A further experiment was made in which an ingot was cast generally in the manner described in this paper, but nine minutes after casting the head portion was filled up with molten steel, and no air-blast or charcoal used. The result was unsatisfactory, showing that this method would not take the place of the one described in this paper.

Another experiment was also made in order to ascertain the nature of an ingot, using slag, but without the feeding device mentioned in this paper. The ingot was poured in the ordinary way and a layer of fine ground slag put on the top. No charcoal, and therefore no blast, was used. The ingot piped and was excellent for soundness. The weight of the discard was, however, considerably greater, being about 12 per cent. to 14 per cent. Moreover, and this is an important point, the segregated portions of the steel did not rise to the top of the ingot so freely. The material was impure, and segregated down to a much lower point.

As regards the time required for ingots to become set, it may be interesting to describe the following experiment carried out at the Hecla Works:

Ingots 9 in. and 18 in. square were cast. In the former case, No. 1515C material, having a composition of 0.20 per cent. carbon and 1.25 manganese, was used; in the latter case, No. 1978A material, 0.40 per cent. carbon and 1.34 per cent. manganese.

To determine the condition of the interior mass, a thin iron rod was inserted in the casting at short intervals after casting.

The following data is interesting, showing the time required for fluid steel in ingots of this particular size to become "set":

TABLE V.

9-inch Ingot		18-inch Ingot.	
Time after Casting.	Distance set up the Ingot from the Bottom.	Time after Casting.	Distance set up the Ingot from the Bottom.
Minutes.	Inches.	Minutes.	Inches.
5	4	25	6
10	6	40	13
18	40	55	55
22	45	60	58
	Complete Solidification.		Complete Solidification.

The author takes this opportunity of thanking Mr. G. C. Lloyd, the secretary of the Iron and Steel Institute, and his assistant, Mr. L. P. Sidney, for information furnished and assistance rendered with regard to the bibliography; also Messrs. I. B. Milne, T. G. Elliot, W. J. Dawson and others for the assistance they have given in carrying out this research, the labors of which have been considerable; also Mr. H. Steel and Mr. E. H. Saniter, of Messrs. Steel, Peech & Tozer, Ltd., The Ickles, Sheffield, for their assistance in connection with the rolling of most of the rails referred to in this paper.

In conclusion, to sum up briefly the results of this research, it may be said that in order to obtain sound rolled or forged products, for example sound rails, there must first be sound steel in the ingots themselves. This means that it is necessary to use steel of piping nature, consequently the ingots from such piping steel must be properly fed. No doubt there are other suitable methods besides those described in this paper for obtaining such sound ingots, but it is doubtful whether these can favorably compare in simplicity, cheapness of operation and in other respects. The author trusts, however, by means of the information now set forth, it will be seen that an attempt has been made to arrive at and place upon a scientific basis the underlying principles concerning the casting of sound steel, the manner in which it cools, segregates and pipes. This is also further dealt with in the accompanying separate paper on "Segregation in Steel Ingots."

A.—*Methods of Casting.*			
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1883	Pourcel, A.	Notes on the Manufacture of Solid Steel Castings.	Journal of the Iron and Steel Institute, 1883, No. II. p. 509.
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1888	Thwaite, B. H.	Note on the Production of Solid Steel Ingots.	Iron, vol. xxxi. p. 551.
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1891	Anon.	The Hinsdale Process for Casting Solid Ingots.	Iron Age, vol. xlvii. p. 242. Engineering and Mining Journal, vol. li. p. 611.
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1905	Anon.	New Methods of Casting Ingots.	Iron and Coal Trades Review, vol. lxxi. p. 2114.
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B.—*Production of Sound Steel.*			
1877	Gautier, F.	Solid Steel Castings.	Journal of the Iron and Steel Institute, 1877, p. 40.
1877	Euverte.	Aciers sans soufflures.	Bulletin de la Société des Ingénieurs Civils de France, 1877, pp. 329, 367 and 375.

B.—*Production of Sound Steel (continued).*

Year.	Name of Author.	Title	Source.
1880	Müller. F C. G.	Ueber die Ursachen urdichter Stahlgüsse.	Glaser's Annalen für Gewerbe und Bauwesen, vol. vii. pp. 138 and 174.
1885	Campbell. H H.	The Homogeneity of Open-hearth Steel.	Transactions of the American Institute of Mining Engineers, vol. xiv. p. 358.
1895	Smith-Casson. R	Small Cast Steel Ingots.	Journal of the Iron and Steel Institute, 1895, No. II. p. 210.
1895	Odelstjerna	Rısse und Assenfehler der Gussblöcke.	Berg- und Hüttenmannische Zeitung, vol. liv. p. 420.
1902	Riemer A	Ueber Inhomogenität der Weichen Basischen Martinblöcke.	Stahl und Eisen, vol. xxii. p. 269.
1902	Wahlberg, A	The Influence of Chemical Composition on Soundness of Steel Ingots.	Journal of the Iron and Steel Institute, 1902, No. I. p. 333.
1903	Sauveur, A., and Whiting, J.	Casting of Pipeless Ingots by the Sauveur Overflow Method.	Proceedings of the American Society for Testing Materials, vol. iii. p. 129.
1904	Anon.	Weitere Entwicklung des Riemerschen Verfahrens zur Herstellung dichter Stahlblöcke.	Stahl und Eisen. vol. xxiv. p. 392.
1905	Daelen, R. M.	Die Verfahren zur Verhütung der Lunkerbildung in Stahlblöcken.	Stahl und Eisen, vol. xxv. p. 923.
1905	Wedding H	Untersuchung über den Ursprung eines Blasenraumes in einem Flusseisenblöcke.	Stahl und Eisen, vol. xxv. p. 832.
1905	Beikirch. F O	Verfahren zur Verhütung der Lunkerbildung in schweren Rohstahlblöcken.	Zeitschrift des Vereines deutscher Ingenieur, vol. xlix. p. 1342. Stahl und Eisen, vol. xxv. p. 865.
1906	Riemer, J.	Ueber die Bildung von Hohlräumen in Stahlblöcken und die Mittel zu ihrer Verhinderung.	Stahl und Eisen, vol. xxvi. p. 185.
1906	Fischer, R	The New Process of the Gutehoffnungshutte for Producing Ingots free from Pipes.	Giesserei Zeitung, Dec. 15, 1906.
1906	Kusl, G	Blowholes and Empty Spaces in Cast Iron and Steel.	Stahl und Eisen.
1907	Hofer, G.	Die Herstellung blasenfreier Stahlgussstücke.	Giesserei Zeitung, vol. iv. p. 353.
1907	Obholzer, A.	Zur Frage der Vermeidung von Lunkerbildung.	Banyászati és Kohászáti Lapok, vol. xxxviii. p. 457. Stahl und Eisen, vol. xxvii. pp. 1117 and 1155.
1910	Paravicini.	Zur Verminderung der Lunkerbildung.	Stahl und Eisen, vol. xxx. p. 215.

B.—*Production of Sound Steel (continued).*

Year.	Name of Author.	Title.	Source.
1911	Osann, B.	Das Lunkern des Eisens.	Stahl und Eisen, vol. xxxi. p. 673.
1912	Hadfield, Sir R. A.	The Production of Sound Steel.	Iron Age, vol. lxxxix. p. 296.
1912	Douteur, M.	Nouveaute en Métallurgie Premier Partie—Les procécédés, actuels de solidification de l'acier: Deuxieme Partie — Nouvelle méthode de Mathieu Douteur: Troisième Partie —Applications de nouveau procédé à des usage spéciaux.	Paris, Institut du Mois Scientifique et Industriel, 1912.
1912	Corbiau, J.	Nouveau Procédé de Coulée des Lingots d'Acier.	Revue de Métallurgie, May 1912.

C.—*Piping.*

1888	Crane, T. S.	The Piping of Steel Ingots.	Transactions of the American Society of Mechanical Engineers, vol. x. p. 592.
1903	Weber, F. C.	Preventing Pipes and Blowholes in Ingots and Castings.	Iron Age, Nov. 12, 1903, p. 6.
1906	Henry M. Howe.	Piping and Segregation in Steel Ingots.	Preliminary Paper, London Meeting of American Institute of Mechanical Engineers, July 1906.
1906	Dickenson, E. L.	Pipes and Blowholes.	Paper read before the Sheffield University Students' Engineering and Metallurgical Society, 1906.
1906	Schwarz, C. de	Use of Oxygen in removing Blast-furnace Obstructions. (Mentions the use of Oxygen Flame for removing Pipe in Ingots.)	Journal of the Iron and Steel Institute, 1906, No. 1. p. 125.
1906	Lilienberg, N.	Piping in Steel Ingots.	Transactions of the American Institute of Mining Engineers, vol. xxxvii. p. 238.
1907	Obholzer, A.	The Methods adopted in the Hungarian Government Steel Works to avoid Piping in Steel Ingots.	Iron and Coal Trades Review, Aug. 9, 1907. Journal of the Franklin Institute, July 1907. Stahl und Eisen, July 31, 1907.
1908	Springer, J. F.	Piping in Steel Ingots: Methods for its Reduction and Elimination.	Cassier's Magazine, vol. xxxv. p. 426.

C.—*Piping (continued).*

YEAR.	NAME OF AUTHOR.	TITLE.	SOURCE.
1909	Springer, J. F.	The Riemer Hot-Top Process of preventing Piping in Steel Ingots.	Iron Trade Review, vol. xliv. p. 1157.
1910	Howe, Henry M.	Piping in Steel Ingots: Influence of Top Lag on the Depth of the Pipe.	Iron Age, Jan. 6, 1910.

D.—*Segregation.*

1881	Snelus, G. J.	On the Distribution of Elements in Steel Ingots.	Journal of the Iron and Steel Institute, 1881, No. II. p. 379.
1884	Cheever, B. W.	Note on the Segregation of Impurities in Bessemer Steel Ingots on Cooling.	Transactions of the American Institute of Mining Engineers, vol. xiii. p. 167.
1893	Hogg, T. W.	Segregation.	Journal of the Society of Chemical Industry, vol. xii. p. 236.
1893	Pourcel, A.	Segregation and its Consequences in Ingots of Steel and Iron.	Transactions of the American Institute of Mining Engineers, vol. xxii. p. 105.
1898		The Physics of Steel. (A discussion on A. Pourcel's paper on "Segregation" and others.)	Transactions of the American Institute of Mining Engineers, vol. xxiii. p. 608.
1901	Fay, H.	Segregation of Phosphorus in a Piece of Cold-Rolled Shafting.	Metallographist, vol. iv. p. 115.
1901	Wahlberg, A.	Variations of Carbon and Phosphates in Steel Billets.	Journal of the Iron and Steel Institute, 1901, No. II. p. 29.
1902	Andrews, T	Effect of Segregation on Strength of Steel Rails.	Transactions of the Society of Engineers, 1902, p. 209.
1903	Stead, J. E	The Segregatory and Migratory Habit of Solids in Alloys and in Steel below the Critical Points.	Journal of the Society of Chemical Industry, vol. xxii. p. 340.
1903	Weston, B. F	Segregation and Diffusion in Steel.	Iron Age, May 19, 1904, p. 28.
1904	Talbot, B.	Segregation in Steel Ingots.	Journal of the Iron and Steel Institute, 1905, No. II. p. 204.
1905	Stead, J. E.	Crystallisation and Segregation of Steel Ingots.	Proceedings of the Cleveland Institution of Engineers, 1905-1906, p. 163.
1906	Huston, C. L.	Experiments on the Segregation of Steel Ingots in its Relations to Plate Specifications.	Proceedings of the American Society for Testing Materials, vol. vi. p. 182.
1906	Stead, J. E.	Segregation in Steel Ingots.	Engineering, Sept. 21, 1906.

D.—*Segregation (continued).*

Year.	Name of Author.	Title.	Source.
1907	Howe, H. M.	Piping and Segregation in Steel Ingots.	American Institute of Mining Engineers.
	Dudley, P. H., and Others.	Discussion of Howe's Paper.	
1907	Stead, J. E.	Segregation in Steel.	Institution of Civil Engineers, Engineering Congress, 1907, Section IV. p. 94.
1907	Breuil, P.	Copper Steels. Chapter III.—Segregation in Ingots.	Journal of the Iron and Steel Institute, 1907, No. II. p. 1.
1907	Howe, H. M.	Segregation in Steel Ingots.	School of Mines Quarterly, vol. xxix. p. 238.
1907	Howe, H. M.	A Further Study of Segregation in Ingots.	Engineering and Mining Journal, vol. lxxxiv. p. 1011.
1907	Howe, H. M.	Piping and Segregation in Steel Ingots.	Transactions of the American Institute of Mining Engineers, vol. xxxviii. pp. 3 and 924, vol. xxxix. p. 818.
1909	Howe, H. M.	Influence of Ingot Size on the Degree of Segregation in Steel Ingots.	Transactions of the American Institute of Mining Engineers, vol. xl. p. 644.
1910	Knight, S. S.	Observations on Segregation Phenomena as applied to Cast Steels.	Paper presented at the Meeting of the Philadelphia Foundrymen's Association, March 2, 1910. Iron Trade Review, vol. xlvi. p. 475.
1910	Waterhouse, G. B.	The Influence of Titanium on Segregation in Bessemer Rail Steel.	Proceedings of the American Society for Testing Materials, vol. x. p. 201.
1910	Wust, F., and Fester, H. L.	Der Einfluss der Seigerungen auf die Festigkeit des Flusseisens.	Internationaler Kongress für Bergbau, Hüttenwesen, Angewandte Mechanik und Praktische Geologie, Düsseldorf, 1910.
1910	Hadfield, Sir R. A.	Expériences sur la Ségrégation dans les Lingots d'Acier.	Revue de Métallurgie, Mémoires, vol. vii. p. 1133.
1910	Knight, S. S.	Further Observations on the Segregation of the various Metalloids in Steel.	Iron Trade Review, vol. xlvi. p. 926.
1912	Heyn, E., and Bauer, O.	Beitrag zur Frage der Seigerungen in Flusseisen.	Stahl und Eisen, vol. xxxii. p. 402.

E.—*Gases.*

1881	Stubbs.	Discussion on John Parry's Paper on Hydrogen and Carbonic Oxide in Iron and Steel.	Journal of the Iron and Steel Institute, 1881, No. I. p. 199.

E.—*Gases (continued).*

YEAR.	NAME OF AUTHOR.	TITLE	SOURCE.
1883	Egleston, Professor T	Gases contained in Steel.	
1903	Weber, F C	Eliminating Gases and Slags from Molten Steel.	Iron Trade Review, May 28, 1903, p. 53.
1908	Belloc, G.	Gaz occlus dans un Acier au Nickel special.	Revue de Métallurgie, Mémoires, vol. v. p. 571.
1908	Belloc, G.	Gaz occlus dans les Aciers.	Revue de Métallurgie, Mémoires, vol. v. p. 469.
1910	Heroult, P L. T	Presence and Influence of Gases in Steel.	Transactions of the American Electrochemical Society, vol. xvii. p. 135.
1910	Auchy G	Mechanically-held Impurities in Steel.	Iron Age, Jan. 13, 1910.

F —*Compression.*

1868	Henderson, J.	Process for Casting Steel under High Pressure by means of Gunpowder.	Scientific American, May 2, 1868.
1875	Whitworth, Sir J	On Fluid-compressed Steel and Guns.	Proceedings of the Institution of Mechanical Engineers, 1875, p. 268.
1877	Considère	Compression of Fluid Steel	Société de l'Industrie Minerale, March 1877.
1879	Davis, A	The Consolidation of Fluid Steel	Journal of the Iron and Steel Institute, 1879, No. II. p. 476.
1879	Anon	Compressed Steel. A Description of the Jones Process at the Edgar Thomson Steel Co.	Engineering, vol. xxviii p. 83.
1880	Davis A	Steel Compression by Steam.	Proceedings of the Institution of Mechanical Engineers, 1880, p. 396.
1888	Greenwood W H	The Treatment of Steel by Hydraulic Pressure and the Plant Employed for the Purpose.	Minutes of Proceedings of the Institution of Civil Engineers, vol. xcviii. p. 83.
1889	Greenwood, W H., I.C.E	The Treatment of Steel by Hydraulic Pressure.	
1894		Report of Board appointed by the United States Government to inquire into the Cost of a Plant for the Fluid Compression of Gun Ingots.	Proceedings of the United States Naval Institute, vol. x. No. IV. p. 831.
1901	Fay, A. E.	The Compression of Fluid Metals.	Iron Age, Jan. 31, 1901, p. 29.
1902	Harmet, H	The Compression of Steel by Wire-drawing during Solidification in the Ingot Mould.	Journal of the Iron and Steel Institute, 1902, No. II. p. 146.

F.—*Compression (continued).*

YEAR.	NAME OF AUTHOR.	TITLE.	SOURCE.
1902	Daelen, W.	The Compression of Steel Ingots during Congelation in the Mould.	Stahl und Eisen, Nov. 15, 1902.
1902	Wille, Major-General.	Using the Ingot Unforged as opposed to Krupp's Forging and Compression Method.	
1903	Riemer, J.	Ein neues Verfahren zum Verdichten von Stahlblöcken in flüssigem Zustande.	Zeitschrift des Vereines deutscher Ingenieur. vol. xlvii. p. 1675.
1905	Demozay M	Sur le mode d'action de la presse à forger et les deformations d'un Metal Comprimé à chaud.	Revue de Metallurgie, April 1905.
1906	Capron, A. J	Compression of Steel Ingots in the Mould.	Journal of the Iron and Steel Institute, 1906, No. I. p. 28.
1906	Wiecke, H.	Das Pressen flüssigen Stahles nach dem Harmet-Verfahren unter besonderer Berücksichtigung der Einrichtung auf dem Oberbilker Stahlwerk.	Zeitschrift des Vereines deutscher Ingenieur, vol. l. p. 1279; Stahl und Eisen, vol. xxvi. p. 628.
1907	Zalinski E. L.	Compression of Steel by Wire-drawing during Solidification in the Ingot Mould.	Journal of the United States Artillery, Iron Trade Review, vol. xli. p. 300.
1908	Lilienberg N	The Compression of Semi-liquid Steel Ingots.	Journal of the Franklin Institute, vol. clxv. p. 121.
1908	Osann, B	Das Harmetverfahren im Martinbetriebe der Gewerkschaft "Deutscher Kaiser" in Bruckhausen.	Stahl und Eisen, vol. xxviii. p. 1601.
1909	Springer, J. F	The Harmet Process of Ingot Compression.	Iron Age, vol. lxxxiii. p. 2002.
1909	Stoughton, B.	The Physical Quality of Steel which has been subjected to Compression during Solidification.	Proceedings of the American Society of Testing Materials, vol. ix. p. 348.
1909	Beutter, F	Développement du procédé de compression de l'acier par tréfilage.	Revue de Métallurgie, Mémoires, vol. vi. p. 75.

G.—*Manufacture of Ingots for Special Purposes.*

1881	Gautier, F	On the Application of Solid Steel to the Manufacture of Small Arms Projectiles and Ordnance.	Journal of the Iron and Steel Institute, 1881, No. II. p. 452.
1888	Cubillo, L.	On Steel Castings for the Manufacture of Guns.	Journal of the Iron and Steel Institute, 1888, No. I. p. 151.

G.—*Manufacture of Ingots for Special Purposes (continued).*

Year.	Name of Author.	Title.	Source.
1888	Cubillo, L.	On the Manufacture and Treatment of Steel for Field-guns.	Journal of the Iron and Steel Institute, 1888, No. I. p. 123.
1889	Hunt, R. W.	Fracture of Steel Rail Ingots.	Iron Age, vol. xliii. p. 196.
1896	Campbell, H. H.	The Manufacture and Properties of Structural Steel.	New York, 1896.
1900	Carulla, F. J. R.	Ingots for Gun-tubes and Propeller Shafts.	Journal of the Iron and Steel Institute, 1900, No. I. p. 163.
1909	Anon.	Die Herstellung von Hohlblocken.	Giesserei Zeitung, vol. v. p. 235.
1909	York, J. E.	A Reliable Steel Rail, and how to make it.	Transactions of the American Institute of Mining Engineers, vol. xl. p. 341.
1912	Cubillo, L.	Manufacture and Treatment of Steel for Guns.	Journal of the Iron and Steel Institute, 1912, No. I.
		H.—*Working and Treatment of Ingots.*	
1880	Chernoff, D.	On the Structure of Cast Steel Ingots.	Proceedings of the Institution of Mechanical Engineers, 1880, p. 152.
1882	Gjers, J.	On the Successful Rolling of Steel Ingots with their own Initial Heat by means of the Soaking Pit Process.	Journal of the Iron and Steel Institute, 1882, No. II. p. 565.
1902	Beutter, F.	L'acier dans sa Lingotière.	Comptes Rendus Mensuels de la Société de l'Industrie Minerale, 1902, p. 78.
1907	Anon.	Ingot Heating Apparatus at the Gutehoffnungshutte.	Engineer, vol. civ. p. 172.
1909	Howard, J. E.	Notes on Tests of Ingots and Derivative Shapes in Progress at Watertown Arsenal.	Proceedings of the American Society for Testing Materials, vol. ix. p. 319.
		I.—*Use of Alloys.*	
1891	Langley, J. W.	Aluminium in Steel Ingots.	Transactions of the American Institute of Mining Engineers, vol. xx. p. 233.
1903	Anon.	Herstellung von poren- und lunkerfreiem Graugufs, Stahlguss und Schmiedestrücken durch Anwendung von Thermit.	Stahl und Eisen, vol. xxiii. p. 925.
1903	Nau, J B.	Manufacture of Sound Castings by Means of Thermit.	Iron Age, Sept. 10, 1903, p. 8.
1912	Canaris, C.	The Use of Anti-piping Thermit in Steel Ingots.	Iron Trade Review, vol. l. p. 701.
1912	Canaris, C.	Ueber die Verwendung von Lunkerthermit bei Flusseisen-Blöcken.	Stahl und Eisen, vol. xxxii. p. 303.

J.—*Closing of Blowholes.*

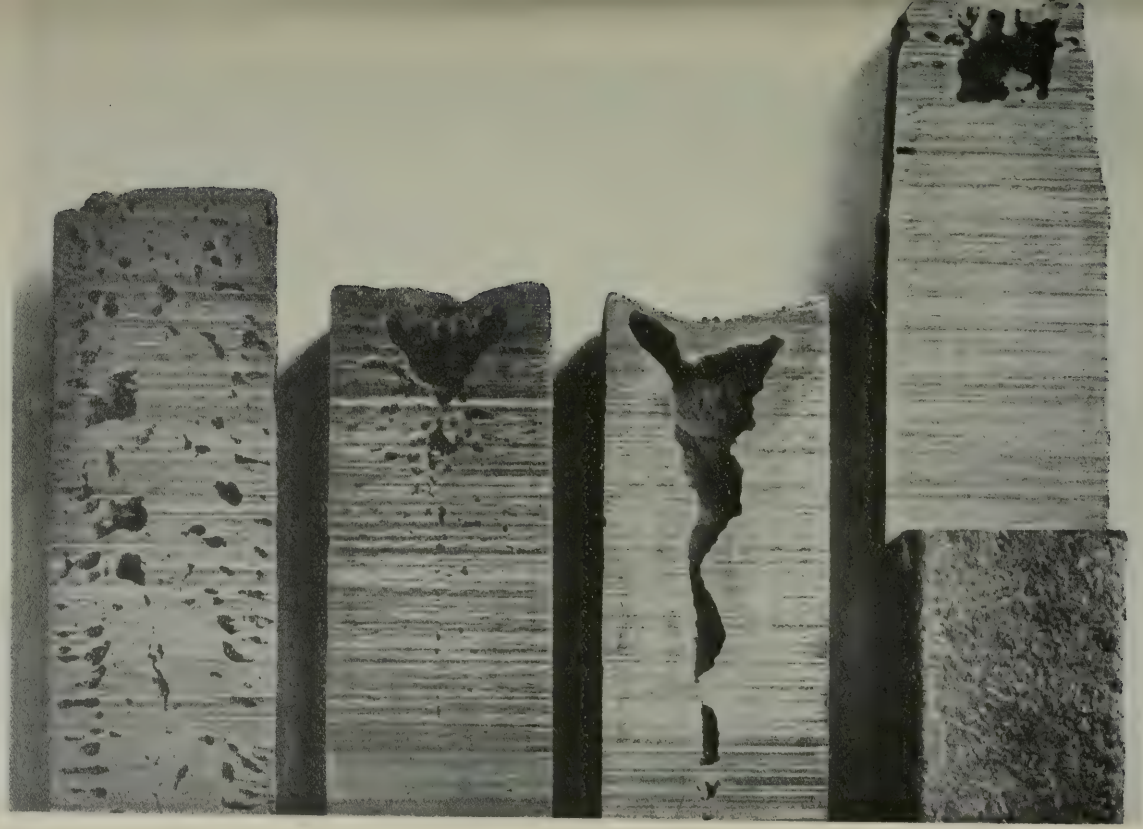
Year.	Name of Author.	Title.	Source.
1881	Müller	Cavities in Cast Steel Ingots.	Journal of the Iron and Steel Institute, 1881, No. II. p. 720.
1886	Head, J	On Blowholes in Open-hearth Steel.	Journal of the Iron and Steel Institute, 1886, No. I. p. 99.
1891	Billy, E. de	La Question des Soufflures dans les Moulages d'Acier.	Genie Civil, vol. xx. p. 126.
1894	Robeson, J. S.	Surface Defects in Ingots.	Iron Age, vol. liv. p. 1062.
1902	Dormus, A. von	Die Blasen und Lungerbildung des Flusseisens.	Zeitschrift des Oesterr. Ingenieur und Architekten Verein, vol. liv. p. 279.
1906	Carr W M	Blowholes in Steel Castings.	Iron Trade Review, Oct. 11, 1906, p. 25.
1906	Kusl W	Blasen und Lunker in Flusseisen und Flusstahl.	Oesterreichische Zeitschrift für Berg- und Huttenwesen, vol. liv. pp. 593 and 610.
1907	Maltitz E von	Blowholes in Steel Ingots.	Transactions of the American Institute of Mining Engineers, vol. xxxviii. p. 412.
1909	Howe, H. M.	The Closing of Blowholes in Steel Ingots.	Proceedings of the American Society for Testing Materials, vol. ix. p. 327.
1910	Howe, H. M	The Welding of Blowholes in Steel.	Proceedings of the American Society for Testing Materials, vol. x. p. 169.
1910	Howe, H. M.	The Closing and Welding of Blowholes in Steel Ingots.	Report of the British Association for the Advancement of Science, 1910, p. 563.
1911	Stead, J E	Notes on the Welding-up of Blowholes and Cavities in Steel Ingots.	Journal of the Iron and Steel Institute, 1911, No. I. p. 54; 1912, No. I. p. 104.
1912	Stead, J. E.	Blowholes in Steel Ingots. Investigation showing the Welding of Cavities in Crucible Steel.	Iron Age, May 30, 1912.
1912	Stead, J. E.	Blowholes in Steel Ingots.	Sheffield Society of Engineers and Metallurgists, 1912.

K.—*Miscellaneous.*

1880	Anon.	On the Structure of Cast Steel Ingots.	
1883	Zoppetti, V	Arte Siderurgica.	Vol. ii. chap. 13, Milan, 1883.
1888	Howe, H. M.	Metallurgy of Steel.	Engineering and Mining Journal, vol. xlvi. pp. 7, 26, and 47.
1894	Robeson, J S.	Surface Defects in Ingots.	Iron Age, December 13, 1894.

K.—*Miscellaneous (continued).*

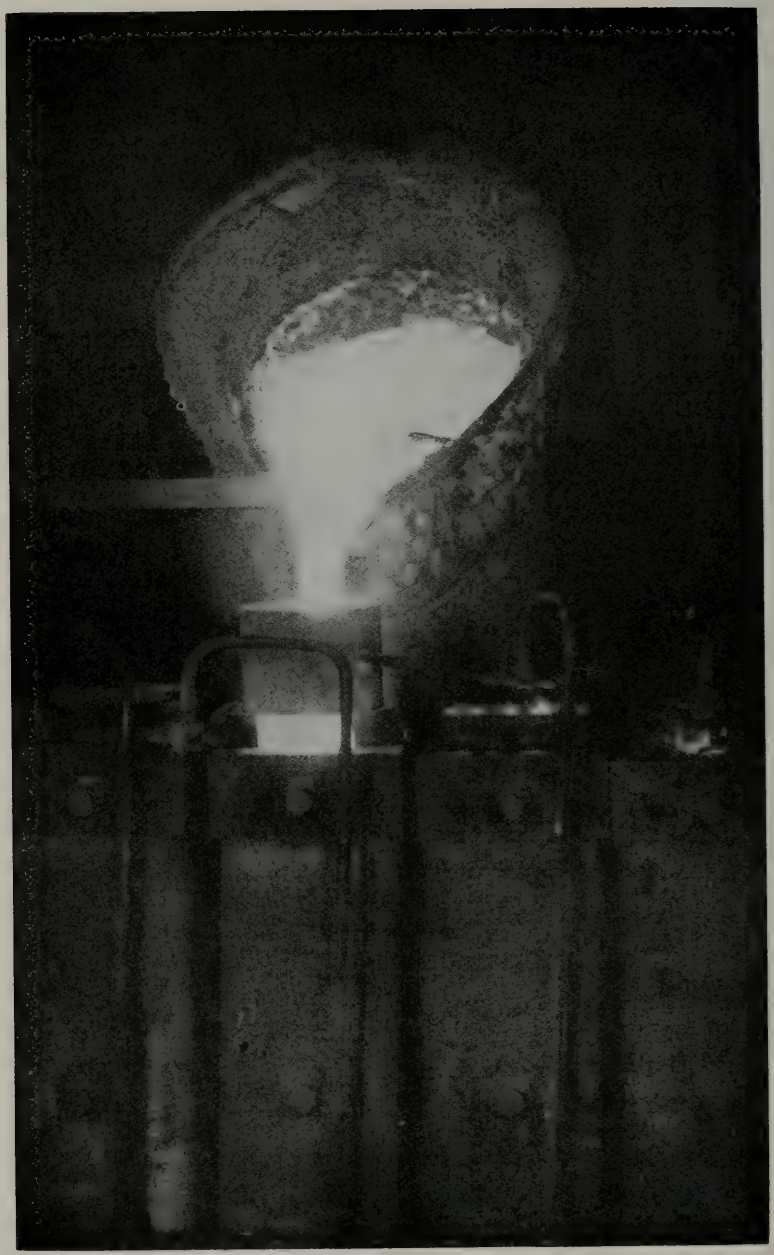
Year.	Name of Author.	Title.	Source.
1897	Ruhfus, A.	On Eliquations in Mild Steel.	Stahl und Eisen, January 15, 1897.
1898	Gages, L.	Traité de Métallurgie du fer	Tome Deuxième, Travail des Métaux, Paris, 1898.
1902	Ledebur, A.	Handbuch der Eisenhüttenkunde.	Leipzig, 1902.
1903	Ridsdale, C. H.	Diseases of Steel.	Journal of the Iron and Steel Institute, 1903, No. II. p. 232.
1903	Howe, H. M.	Iron, Steel, and other Alloys.	Boston, 1903.
1903	Campbell, H. H.	Manufacture and Properties of Iron and Steel.	New York, 1903.
1905	Noble, H.	Fabrication de l'acier.	Chapter xvii. Paris, 1905.
1906	Ruhfus, A.	Vorgänge beim Stahlschmelzen.	Stahl und Eisen, vol. xxvi. p. 775.
1907	Lochner.	Quelques Mots sur les Lingotieres d'acierie.	Revue de Métallurgie.
1908	Howe, H. M.; Campbell, W.; Koken, W. T.	Can Ingotism be Cured by Prolonged Exposure to the Temperature at which Overheating is Cured?	American Society for Testing Materials, 1908.
1908	Stoughton, B.	The Metallurgy of Iron and Steel.	New York, 1908.
1909	Rosenhain, W.	Slag Enclosures in Steel.	International Association for Testing Materials.
1909		Report of Tests of Metals and other Materials for Industrial Purposes.	Vols. i. ii. and iii. in five parts.
1910	Auchy, G.	Mechanically-held Impurities in Steel.	Iron Age, vol. lxxxv. p. 108.
1911	Dichmann, C.	The Basic Open-hearth Process.	London, 1911.
1911	Harbord, F. W., and Hall, J. W.	The Metallurgy of Steel.	London, 1911.
1911	Edwards, C. A.	The Nature of Solid Solutions.	Journal of the Institute of Metals, vol. vi. p. 259.
1912	Howard, J. E.	Report of Accident on the Line of the Lehigh Valley Railroad, near Manchester, New York, August 25, 1911.	Interstate Commerce Commission.



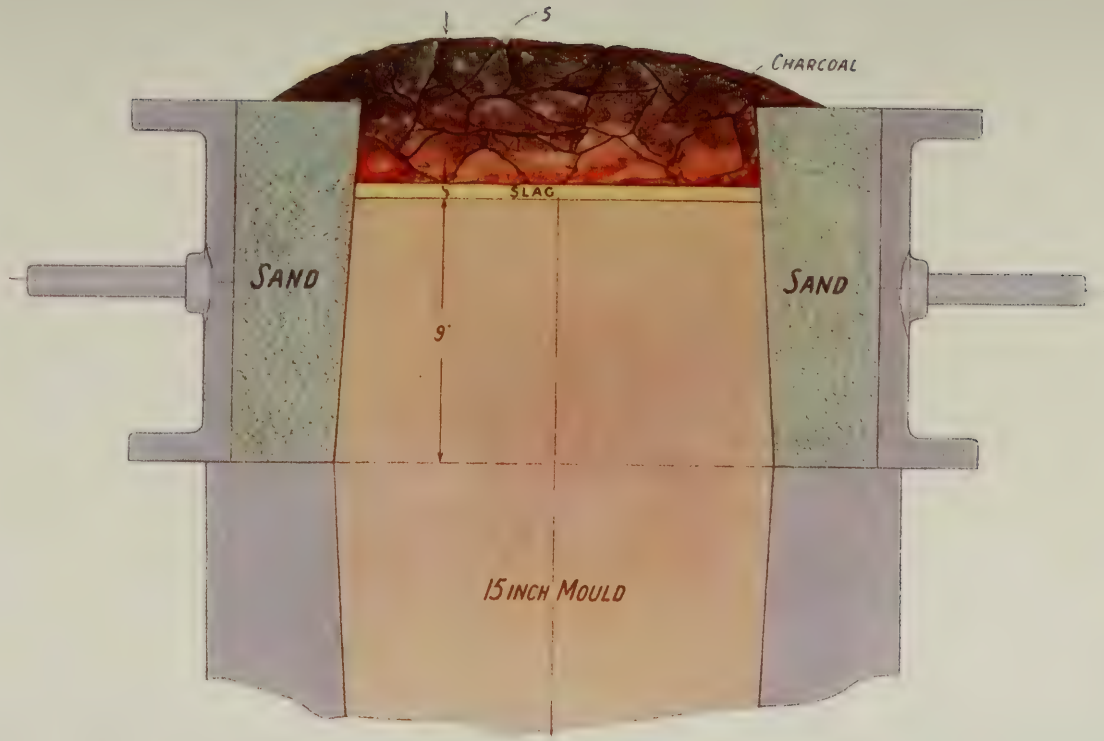
No. 1. No. 2. No. 3. No. 4.

Upper portions of four small ingots (4 inches square) made to illustrate and test the question of soundness and piping.

PLATE III

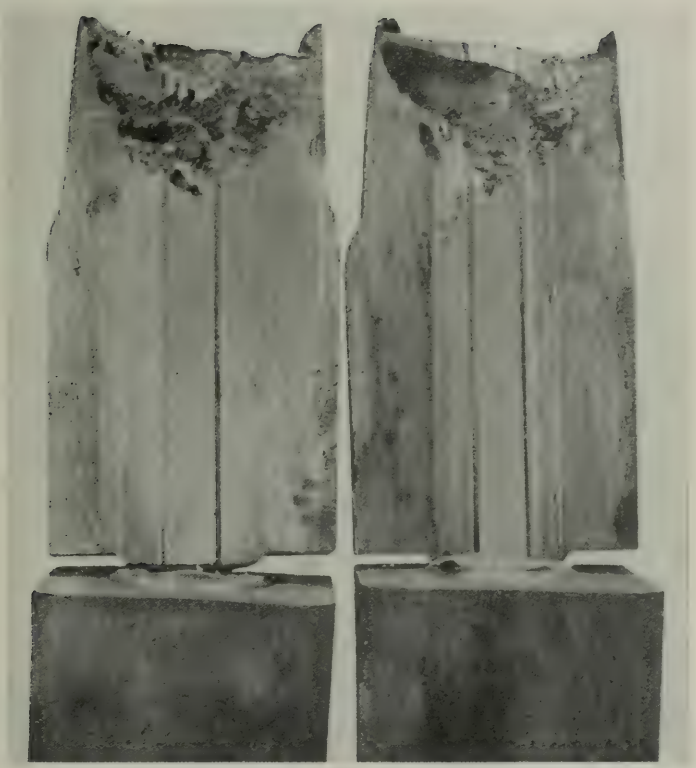


Pouring the ingots described in this paper. Either top or bottom pouring may be employed.



Method of making the Ingots

PLATE II

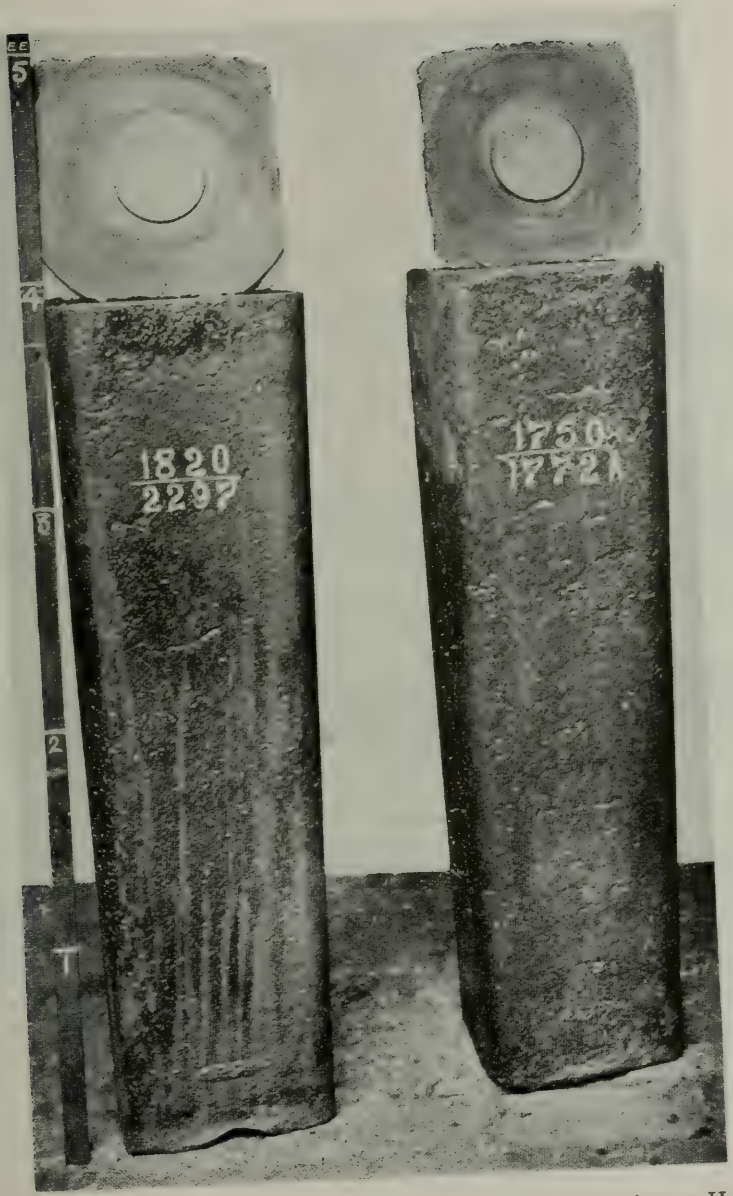


Machined sections of the two ingots referred to in this paper, showing the soundness, and freedom from piping and segregation.

PLATE V

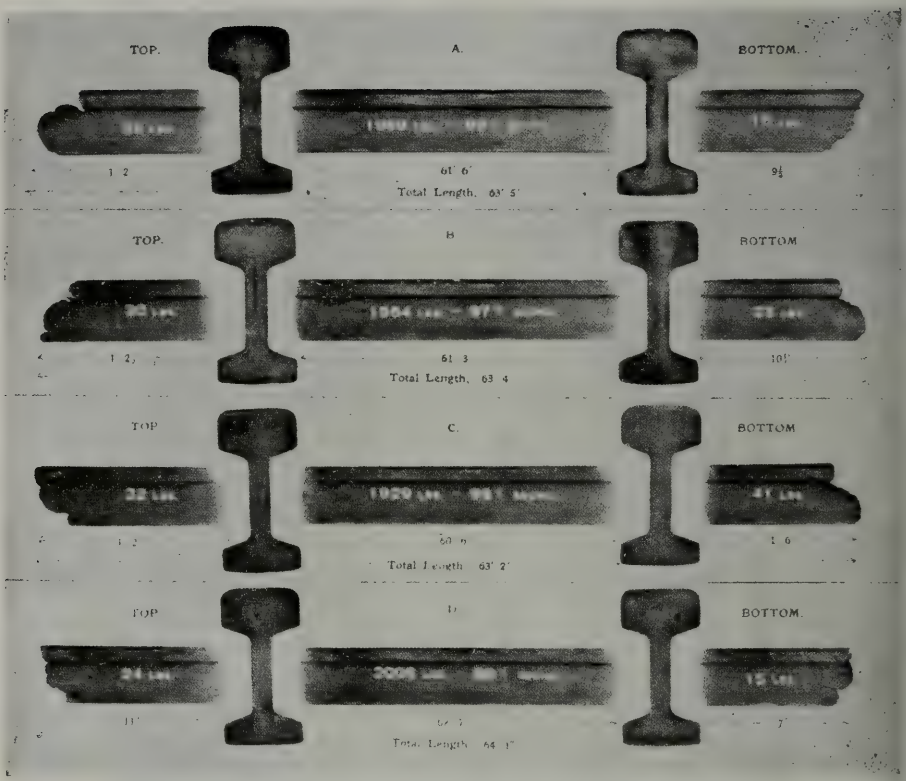
	C. %	S. %	P. %
(1)	0.72	.....	.....
(2)	0.66	0.101	0.064
(3)	0.65	.....	.....
(4)	0.62	0.097	0.061

Ingot referred to on page 463, showing gradual decrease of segregation.

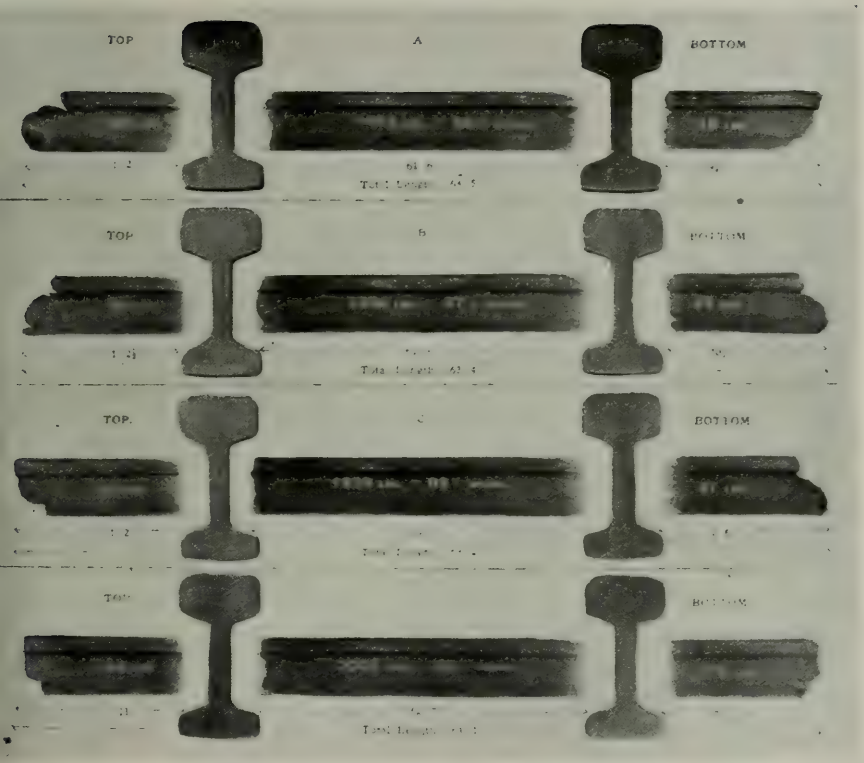


Two Ingots, each weighing 2,300 lbs., showing Machined Section on Head.

PLATE VII

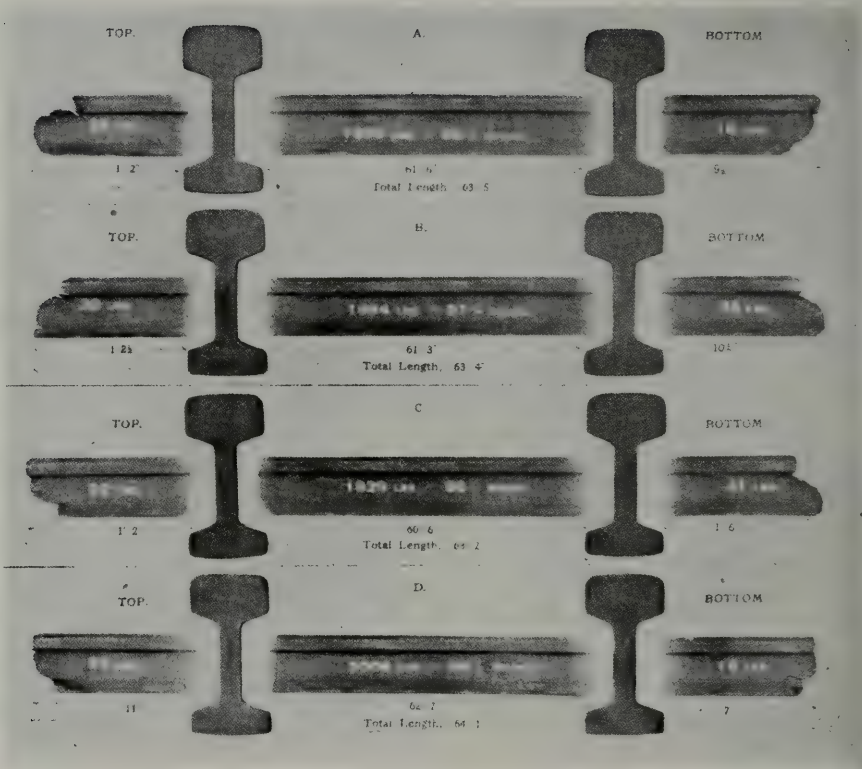


Sulphur Prints of 95-lb. Bull-headed Rails.



Polished Sections of 95-lb. Bull-headed Rails.

PLATE IX



Etched Sections of 95-lb. Bull-headed Rails.

Full Size Polished Section of 95-lb. Bull-headed Rail.

PLATE XI

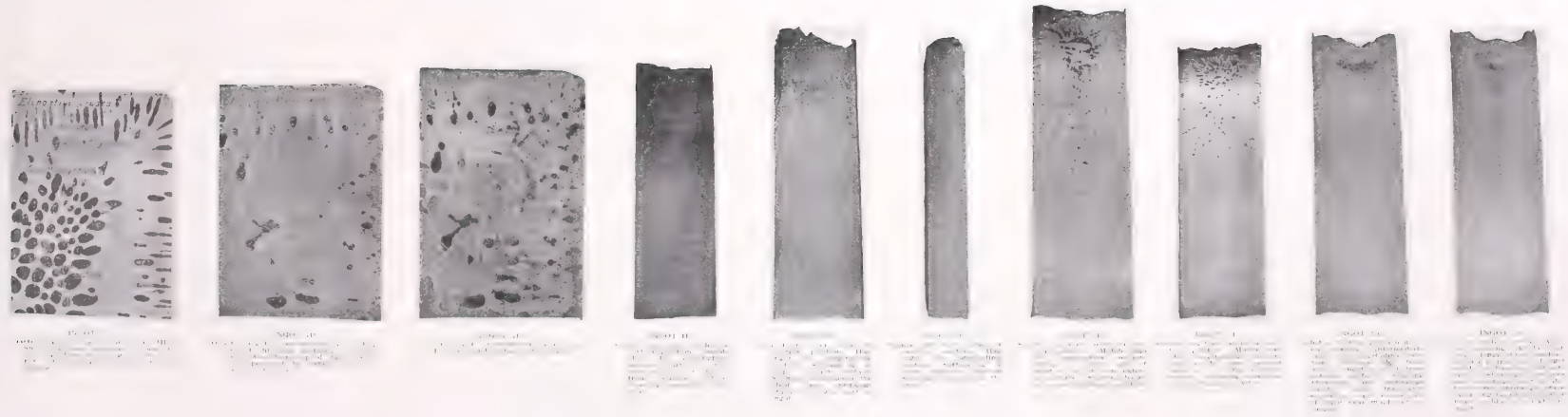
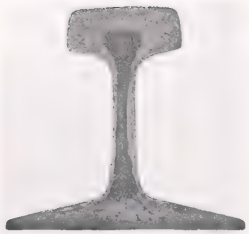
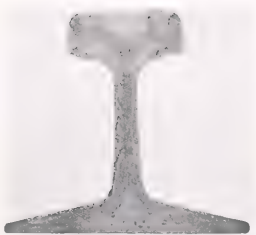
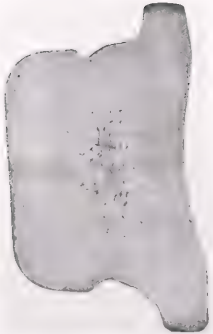


PLATE XII

PLATE XIII







ON A NEW METHOD OF REVEALING SEGREGATION IN STEEL INGOTS.

By Sir Robert Hadfield, F. R. S. (Past-President Iron and Steel Institute).

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In presenting this paper the author suggests that it should be considered with and as bearing upon the subject of his paper on "Methods of Producing Sound Ingots," contributed to the present meeting. The reason for this is that the research now described appears to offer the means of throwing light upon the complex problems met with in relation to the production of sound steel by methods in which segregation and piping troubles, if not entirely absent, are largely reduced. In sound steel which pipes, unless steps are taken to deal with the troubles which accompany such piping, the difficulties of segregation in ingots which are not properly fed has not perhaps altogether been appreciated, as will be seen from the experiments now described.

Whilst knowledge has long been sought as to the changes which take place in the interior of masses of steel during cooling down from the molten to the solid state, few experiments of a definite nature have been undertaken. This has been the more unfortunate because steel of any nature or type, whilst so cooling down, is subject to the development of defects of a somewhat serious character. These chiefly come under the terms "segregation" or "segregated areas," and are largely due to the fact that the two chief deleterious elements, sulphur and phosphorus, always present in steel to a greater or lesser extent, liquate and separate out from the mass in those portions of the ingot or casting which remain fluid for the longest period of time during the cooling down to the solid condition. Carbon and manganese, also to some extent nickel and chromium, also liquate, but they are not directly harmful in the same way as the two elements mentioned.

In other words, it is well known that at a certain stage of the cooling-down process of molten steel the complex phenomenon of liquation is met with and causes much difficulty. Possibly this phenomenon is more marked in its harmful characteristics in iron and its combinations known as steel than in any other metallurgical product. This is no doubt to some extent due to the high temperature which is necessarily employed during the manufacture of steel, which varies from probably about 1,400 deg. C. in alloy steel, such as manganese steel, to about 1,650 deg. C. in molten steel of mild quality. This difficulty is intensified because of the peculiar behavior of the elements present. Whilst sulphur and phosphorus give the most trouble, the above remarks also apply to the element carbon and the metal manganese alloyed with iron, and, as above mentioned, to

a less extent as regards nickel and chromium. This segregation of the elements referred to gives a brittle, impure and weak steel, which in the finished article may prove not merely objectionable but dangerous. There is no proof that segregation occurs in fluid steel itself, that is, all the elements are then well fused and not segregated; the difficulty begins as soon as the mass commences to cool down; in other words, segregation appears to be a function of the lowering of the temperature. Whether this arises owing in some way to the lowering of the tension of combination of the molecules, if one can use this term, is not certain. In any case, however, the difficulty experienced seems to be almost entirely confined to the steel remaining liquid to the latest stage, probably partly through want of ferro-static pressure occurring in the center of the mass. Thus a steel of otherwise suitable composition, that is, sufficiently low in the deleterious elements sulphur and phosphorus, when cooled down will show, upon analysis, an increase of these elements at the segregated areas in some cases amounting to seven or eight times the original percentage. A sample of steel taken whilst fluid from the upper portion of an ingot is equally as pure as the lower portion. The difficulty only arises on cooling down, and in that portion of the ingot or casting where the ferro-static pressure is lowest.

Such segregated area if not removed remains in the casting and becomes drawn out during the forging or rolling, or whilst being otherwise manipulated; thus seriously weak places mechanically will occur in the finished article. In some cases these defects get removed; for example, gun ingots are cast solid and are afterwards usually bored out to remove the segregated areas. But this cannot be done in forgings requiring a solid section, so that the center of disturbance remains present in such areas, in some cases giving rise to the production of articles possessing serious internal weakness which may break, if not at once, later on in service. This has, for example, been noticed in the case of rails, and dangerous accidents have resulted through their breakage.

The author thought that if it were possible to find means of ascertaining how this segregation arises, useful information would be obtained and methods of investigation opened up by which the difficulty could be dealt with and overcome. He therefore presents the results of this research and the methods adopted, which to his knowledge have not before been tried. They are simple, and yet by their use afford considerable information in the desired direction; that is, they show, to some extent, what is going on inside the molten mass during the cooling portion of the process.

The research commenced in this manner. It was reasoned that possibly some addition, preferably metallic, could be made to steel whilst in its molten or partly fluid condition which would give the desired effect. Thus upon breaking up the ingot when cold, if it would show the presence of the added metal in some clear and definite manner, such as by difference in color, useful information would be obtained. The author, therefore, after a considerable number of experiments with various

metals, selected copper, which, by its slightly higher specific gravity as compared with iron, would have a tendency to fall or drop down the central portion of the ingot being experimented upon; moreover, by its distinctive color at the parts where it is alloyed with the iron its presence would be apparent.

In the first instance (Experiment No. 5893, Plate I, Figs. 1 to 5), a small ingot 2½ in. square and about 30 in. in length was poured into an ingot mold in the ordinary way. The composition was as follows:

	Per cent.
Carbon	0.41
Silicon	0.53
Manganese	1.32

This ingot was furnished with a sand head, as shown by Plate III, Fig. 7, the object of the sand head being to feed the shrinkage taking place in the remaining portion of the ingot. In other words, the ingot mold itself being of cast iron and the ingot head of sand, the molten metal in the latter remains fluid for a much longer time and helps to feed the shrinkage or contraction of the remaining portion of the ingot when it cools down to the solid condition. A similar method of overcoming piping with a suitable arrangement for carrying on the compression during cooling is dealt with very fully in the accompanying paper on "Method of Producing Sound Ingots."

Soon after the small 2½-in. ingot was cast, a few ounces of molten copper was poured into the center of the hollow space remaining in the sand head, about 1½ in. from the outside. The time which elapsed between the casting of the ingot and the pouring on of the copper into the hollow space was approximately 30 seconds. In this case, the result of pouring the molten copper, which was added in a comparatively cool condition—that is, it was not as hot or fluid as it should have been—appeared to be to chill the upper portion in the sand head. At first it was thought the copper had not penetrated the molten steel of the ingot at all. However, on breaking off the ingot head and making a longitudinal fracture, it was discovered that the copper had forced its way through a hole in the center of the ingot of very small diameter, and penetrated nearly the *full length* of the ingot, an interesting result and somewhat unexpected. Figs. 1 to 5 (Plate I) show the appearance of the ingot when it was broken up under the hammer. The cuprous areas are indicated in red as they appeared in the fractures of the material.

The copper had penetrated into those portions of the ingot where piping usually takes place, and thus indicated the exact location where what may be termed inter-crystalline unsoundness or segregation is developed. It may be mentioned that this particular type of inter-crystalline unsoundness is not usually seen or detected in the fracture of an ordinary ingot when cold; it is only revealed by a polished section after etching. The cuprous areas in these small ingots probably represent these segregation areas.

This experiment showing interesting promise, the research was con-

tinued on several ingots 6 in. square, each about 3½ ft. in length and weighing about 4 cwts. The design of these was similar to the small ingot just referred to; that is, the ingot itself was cast in an iron mold with the head portion of sand.

Into the head of the first 6-in. ingot, No. 7455-1978A, 15 lbs. of fluid copper, previously melted in a plumbago crucible, were poured half a minute after casting. The addition of the copper was carried out somewhat earlier than at first intended, because in the previous experiment on the ingot of small size the copper appeared to cause the steel in the head of the ingot to set. In the case, however, of the 6-in. ingot, the copper did not cause the steel in the head to set as expected; most of it descended by its superior gravity almost bodily to the lower portion of the ingot. This ingot was parted into two portions so as to give a central longitudinal section; the section was then etched. Plate II, Fig. 6, is a colored section showing the copper appearance in the cut-up ingot. No. 7455-1978A and Fig. 6a is a section showing the copper appearance in ingot No. 7501-1978A. Plate III, Fig. 7, shows the appearance of the first ingot, the dark portions being those colored by the added copper. From the results obtained it will be noticed that half a minute after casting the ingot appears to have set to a thickness of about ⅝ in. to ⅞ in. along the sides and ⅞ in. on the bottom. In the cuprous areas will be noticed crystals which have the same appearance as the outside envelope.

As in this 6-in. ingot, the copper was found to have been added somewhat too soon to give a full indication of what occurred on the steel reaching its setting or chilling point, the experiment was repeated on an ingot made from Heat No. 7501-1978A. In this case 15 lbs. of molten copper was added after a period of 3½ minutes had elapsed after casting. This steel settled well in the sand test, also in a 2½-in. ingot made at the same time, but the larger ingot was not quite sound. This was not, however, in any way due to the added copper, but to the interior of the mold being slightly damp. The experiment was repeated on a perfectly sound ingot and the results were the same. It was thought, therefore, interesting to present the unsound ingot to show that the same law applied to unsound as to sound steel. The dark areas in Plate III, Fig. 7, show the cuprous portions of the first ingots. These portions are indications of the state in which the interior portion of the ingot existed 3½ minutes after casting. After such a comparatively long interval of time, and in such a small ingot, it is somewhat remarkable that the copper should have descended so deeply. If the copper is added too early, that is, before the steel solidifies, it displaces or penetrates the molten material remaining. If the copper is added when solidification is completed, then it does nothing more than fill up the cavities, or strengthen segregation areas which are not really mechanically solid.

It would appear from these experiments that a valuable source of information is opened up for making tests with regard to rates of cooling, segregation and liquation. Moreover, these results show that the

interior of an ingot, even of small size, and it will be therefore more so in a large ingot, remains hotter for a much longer period than has been thought to be the case. It can, therefore, be more readily understood why segregation proves so harmful, for, owing to this longer time of cooling and the reduction in the ferro-static pressure, naturally much greater opportunity occurs for the liquation of such harmful elements, sulphur and phosphorus. The more quickly the steel sets, the less opportunity is therefore given for this segregation. This fact has long been known in a practical way, but the reason for it has not been so apparent. The results of the present experiments seem to clearly indicate why quick cooling is advantageous. The following are comments upon the various figures:

In Plate IV, Fig. 8, are shown the percentages of the copper found at the respective portions of the ingots Nos. 7455-1978A and 7501-1978A, as marked, described earlier in the paper.

The sulphur prints, Plates V and VI (Figs. 9 and 10), show the distribution of copper in ingot No. 7455-1978A, the cuprous portions being lighter in color than those which are free from copper. It will be noticed that the acicular crystallization of the copper free envelope ends abruptly where it joins the cuprous interior. In the cuprous portion the sulphur is evolved from innumerable small points, whereas in the copper free envelope the sulphur is evolved quite differently, giving an even brown coloration.

The sulphur print Plate VII (Fig. 11) shows the crystalline structure in ingot No. 7501-1978A remarkably well. If the print is examined with a magnifying glass it will be seen that the sulphur is evolved from innumerable minute points, and these points often run into lines parallel to the needle-like crystals formed in the matrix of the ingot.

Plate VIII (Fig. 12) shows a larger ingot of about 14 in. diameter. into the head of which about 28 lbs. of molten copper was poured 15 minutes after casting. The head was then covered with charcoal, and was not afterwards disturbed. The ingot was allowed to remain in its mold for one hour. The material was annealed and a section prepared, sulphur printed and etched. The copper was found to have penetrated to within about 9 in. of the bottom, as will be seen, thus showing that even 15 minutes after casting the ingot was fluid at this point and was readily permeated by the copper.

The examination of the sulphur print showed that there appeared to be some segregation at the bottom of the cuprous area. The cuprous portion could be picked out by the somewhat different appearance to the rest of the section.

Plate IX (Figs. 13 and 14) gives the results of scleroscopic tests on two ingots, and also shows the percentages of copper present at different portions.

It may be interesting to state that the relative contraction of copper and steel is as follows:

	Copper	Steel.
Expansion coefficient, solid	0·00001678	0·000011 [1]
,, ,, molten	No data, but higher than for the material in its solid condition	
Specific gravity, solid	8·95	7·85
,, ,, molten	8·21	6·88 †
Total casting shrinkage down to ordinary temperature	1·42	1·50

The molten specific gravities represent figures quoted in the "Standard Handbook for Engineers," from researches of Roberts-Austen and Wrightson.

Probably what has occurred in the ingots described is that upon adding the copper, which is poured onto the top of the ingot, a pipe is formed, and the copper is forced into this by pressure. As the ingot cools down, more pipe is formed; the copper still remains fluid, and keeps such pipe portion filled. As, however, the copper contracts more than the steel, the cavity formed by piping draws upon the supply of molten copper at the top of the ingot. This expands or rises slightly upon setting; nevertheless it contracts more than the surrounding steel. Apparently the contraction of the copper and iron do not take place in the same relative proportion as might be expected.

In conclusion, the author thinks that these experiments should throw some light upon the nature of the phenomena occurring in the cooling down of molten steel to the solid condition.

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*Mild steel. †No. 4 "Cleveland" foundry iron, which is 6.95 when solid.

Fracture at base of head

Fig. 2

4" below head

Fig. 3

8¼" below head

Fig. 4

14¼" below head

Fig. 5

17" below head

Experiment No. 5893.—2½-inch Ingot Showing Where Copper Penetrated.
2½-inch Ingot (Square). Total Length, 30 Inches.

PLATE I

PLATE III

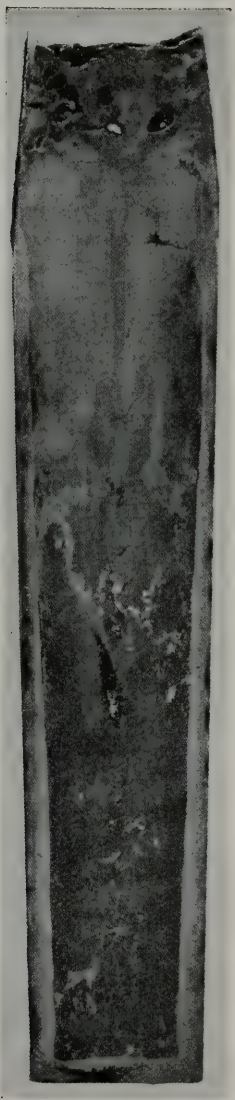


Fig. 7.—Dark Areas Showing Penetration of Copper in Ingot. (See Also Fig. 6, Plate II.)

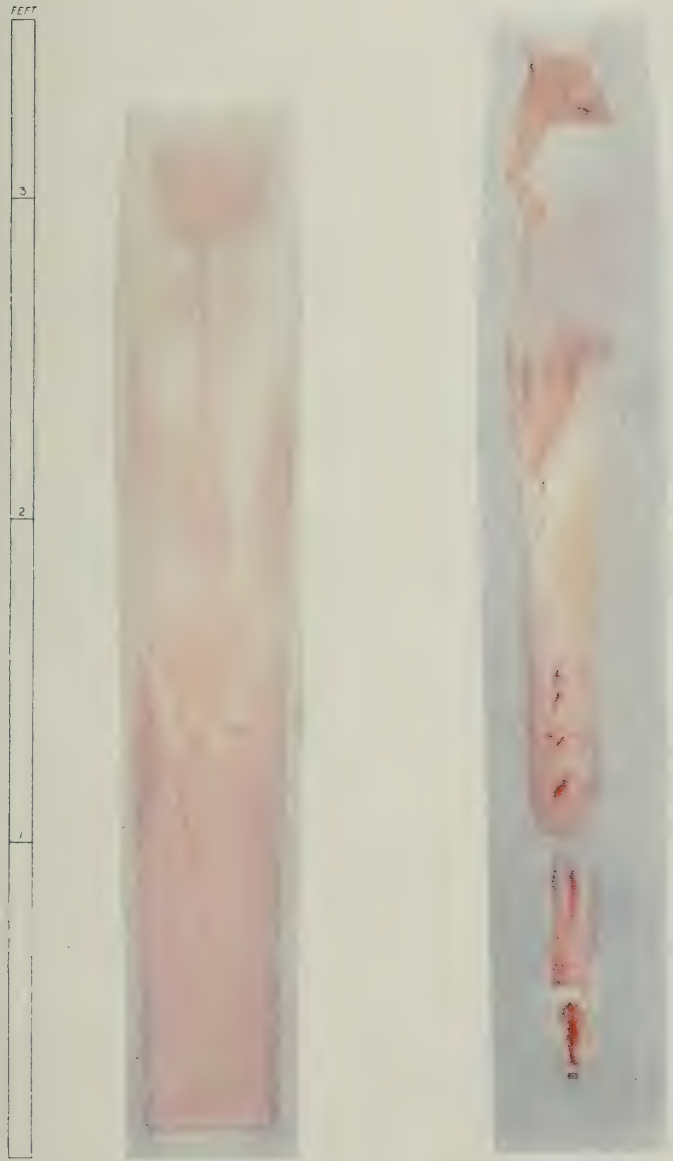


Fig. 6
Ingot No. 7455/1978-A

Fig. 6-A
Ingot No. 7501/1978-A

Colored section of Ingots, showing penetration of Copper

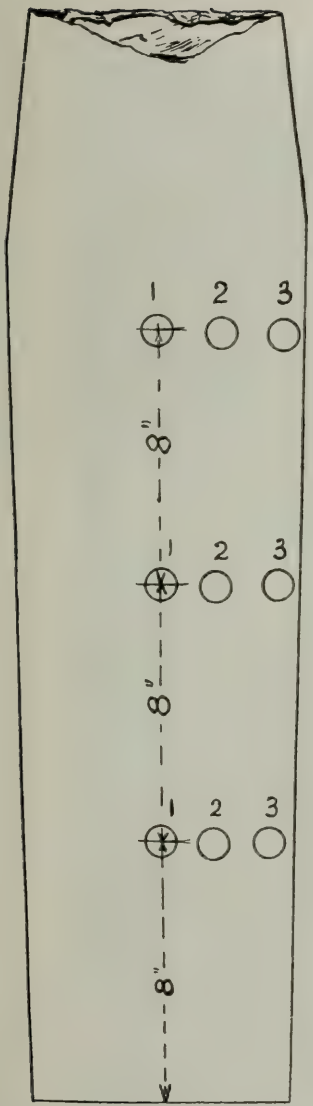


		Fig. 13. *Sound.* 7455/1978A. Cu %	Fig. 14. *Unsound.* 7501/1978A. Cu %
C	1	1·70	6·80
	2	3·41	1·41
	3	0·62	0·07
B	1	4·37	6·00
	2	6·40	0·07
	3	0·089	0·04
A	1	14·20	8·80
	2	15·40	0·23
	3	0·06	0·03

Fig. 8.—Section of one of two different 6-inch Ingots of the following composition, showing the Percentages of Copper at the different portions of the Ingots.

Analysis of the Steel in these Ingots.

Ingot No.	Carbon per cent.	Silicon per cent.	Sulphur per cent.	Phosphorus per cent.	Manganese per cent.
7455/1978A (Fig. 13)	0·45	0·36	0·060	0·061	1·19
7501/1978A (Fig. 14)	0·42	0·42	...	..	1·34

PLATE V

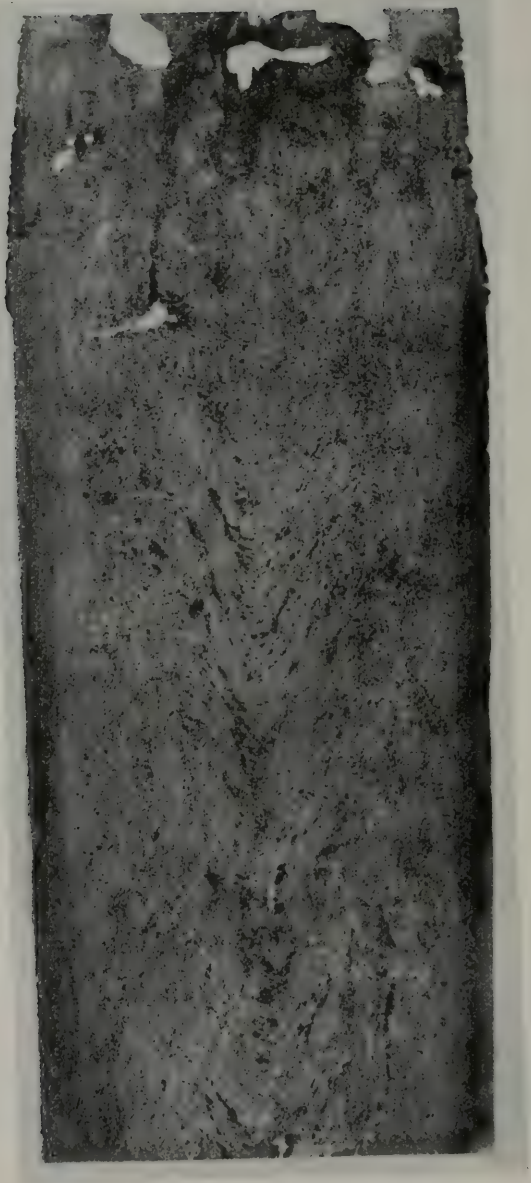


Fig. 9.—Sulphur Print of Ingot No. 7455/1978A.

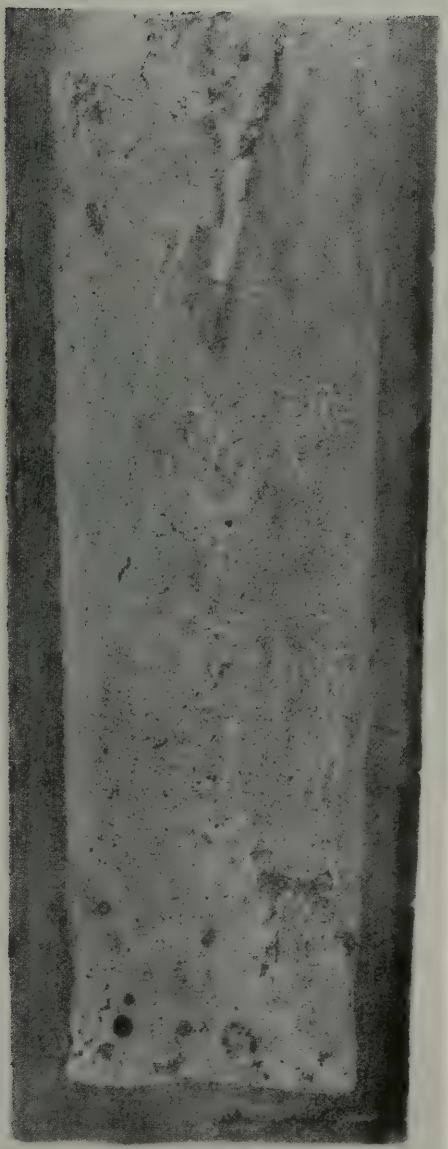


Fig. 10.—Sulphur Print of Ingot No. 7455/1978A.

PLATE VII

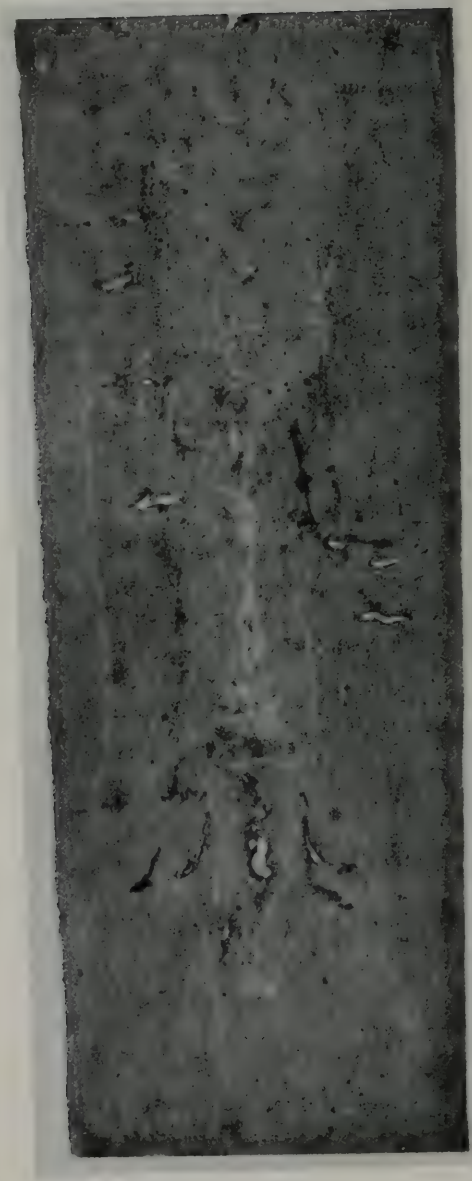


Fig. 11.—Sulphur Print of Ingot No. 7501/1978A.

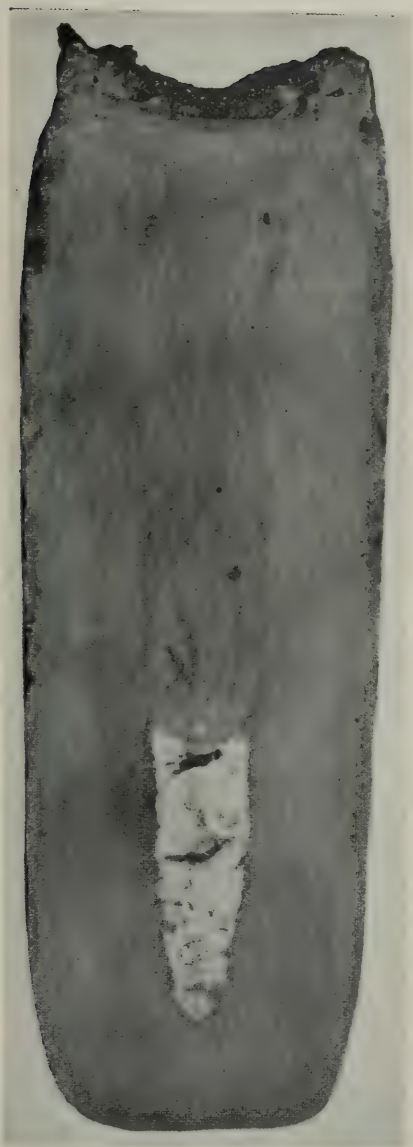


Fig. 12.—Ingot (14 inches diameter), into head of which 28 lbs. of molten copper was poured 15 minutes after casting. Notwithstanding this comparatively long time, the copper is seen to have found its way almost to the bottom.

PLATE IX

BOTTOM OF INGOT
TOP OF INGOT
BOTTOM OF INGOT
TOP OF INGOT

METHOD OF PRODUCING SOUND INGOTS.

DISCUSSION BY W. C. CUSHING.

At the meeting of the Iron and Steel Institute of Great Britain in Leeds, England, on October 1st, Sir Robert Hadfield's papers on "Method of Producing Sound Ingots" and "On a New Method of Revealing Segregation in Steel Ingots" were presented and subsequently discussed by the members. The discussion has been reported in "Engineering," of London, for October 4th, 1912, in "The Engineer," of London, for October 4th and 11th, 1912, and in "The Iron Trade Review," for October 17th, 1912, and the remarks were highly complimentary to the value of the papers. In connection therewith, Mr. Benjamin Talbot agreed with Sir Robert Hadfield in the opinion that the matter of sound ingots was one of extreme importance and that the accidents on railways reported from America and due to rails obtained from defective ingots afforded a proof of this. He was convinced that the production of the sound ingot had to come.

Dr. Stead presented a written discussion of the papers in which he described Mr. Talbot's process, devised 18 months ago, and in operation at Cargo Fleet, for producing sound ingots, which he believed was bound to lead to most important results in the manufacture of rails. The description as given in "The Iron Trade Review" is as follows:

"The ingot is first made absolutely sound by the use of aluminum (called in England aluminium) or silicon, except as to the central pipe. The ingot is quickly stripped and is allowed to stand in the soaking pit for a short time. It is then—while its center is still liquid—sufficiently compressed by a few passes in the cogging mill to reduce its sectional area (for instance from 25 x 25 inches to 18 x 18 inches). The resulting semi-cogged ingot is free from cavity, and is absolutely sound. The practice at present is to return the semi-cogged ingot to the soaking pit in order to equalize the heat, but if this method should come into commercial use, and if other developments in course of time are employed, it may not be necessary to do this. The rails rolled from the upper part of the ingots treated in this way stand the drop tests extremely well. . . .

"When the ingot is taken from the soaking pit, the pipe will be well-developed, and the central portion of the steel is free to flow. When placed on its side at the rolls, the steel will at once flow into the cavity before pressure is applied, while the gases travel along the frozen internal side of the ingot. As soon as sufficient pressure is applied these gases must be forced into the steel itself and remain there in solution or escape into the air.

"Coincidentally, during extension, the layer of steel just below the thick, solid envelope at the stage of solidification at which all steel is quite fragile, not being capable of extension, breaks up into a multitude of small fissures, and these are at once filled with the carbon, sulphur, phos-

phorus, and the rich residual liquid from the layer below, consisting of loosely-packed, pure crystallites of iron and liquid."

At the same meeting, a paper on the "Rolling Mill Practice in the United States" was presented by Dr. J. Puppe, of Breslau, in which he also criticised the quality of the material manufactured in this country. He stated that in Germany the reduction in the cogging-rolls was 14 per cent., and with harder material 11 to 12 per cent., whilst in American practice it was sometimes 24 per cent., from which treatment he considered that the material must suffer considerably. He also called attention to the fact that the Edgar Thomson Works, and Gary Works turned out as much as 4000 tons per 24 hours, which lead him to question whether it were possible at that rate to bestow the requisite care on the work, and considered that this might perhaps explain the breakage of American rails, which he said was more frequent in America than elsewhere. He further called attention to the increased traffic, stating that "the load of goods wagons has increased from 10 tons to 50 tons, and the weight conveyed by a freight train has gone up from 500 to 600 tons to 3000 to 4000 tons. The axle load of goods locomotives is now 25 tons as compared with 11.5 tons formerly. Speeds of 75 miles per hour have to be maintained daily between stops in order to make an average speed of 50 miles per hour. From these considerations it will be seen that the risk of breakages must have increased considerably, especially in view of the low temperatures sometimes prevailing during the winter months.

"Proposals for the improvement of the structure of the metal" (still quoting from "The Engineer") "by lowering the temperature at which the rails were finished and a specified permissible maximum contraction have not proved a sufficient remedy in increasing the resistance to shock and jarring. . . . .

"Naturally the treatment during rolling has a particularly important influence on the rail quality. The initial and final temperatures, the cross section and length of ingot, the proportion of initial and final section to the number of passes, the roll draughting and the treatment of the finished rails, all play an important part. . . .

"*To standardize the amount of discard is beside the mark,* not only on account of the many conditions which influence segregation, but because every ingot requires individual treatment according to the depth of the pipe, which must at all costs be cut out. *If the conditions of manufacture permit that the price may be increased according to the percentage of discard, this may have the effect of a premium for the steel works which took no interest in the improvement of its ingots or in the reduction of pipe.* In German practice the elimination of piping is practicable, and can be perfectly performed; the end surfaces are milled, thus allowing any defects to become visible. Such defects are not revealed by an ordinary saw cut alone, as practised in the United States.

"It is clear, however, that it cannot be immaterial whether a comparatively hard material is rolled down to its final shape in thirty passes with a reduction of 12 per cent. in section at each pass, or in 15 passes with

a 23 per cent. reduction. The finishing temperature is bound to be enormously influenced by the number of passes and the reduction of draught, thus proving the uselessness of taking the contraction as a guide for the finishing temperature; moreover, the structure of the steel, especially at the lower temperature required in the case of the harder kinds, suffers through the too severe squeezing of the metal."

He emphasized the importance of the statement that the rolling should be more gradual and the cooling effect should coincide with the reduction in rolling. If there was a large draught at an intermediate stage of the rolling, there occurred a reheating of the piece, and he believed that in their large plants, with an output of 37 per cent. in 1910, falling to 24 per cent. in 1911, the Americans had overreached themselves as regards present conditions.

The writer has underlined above a most important quotation on the subject of discard, which confirms statements he has hitherto made to define the attitude of your Rail Committee with respect to this vital detail in the "Specifications for Carbon Steel Rails." The method of testing adopted, by which every test piece is broken (generally first nicked for facility of the work), is most valuable, for it enables the inspector to make the examination for interior defects which Dr. Puppe states the German engineer is able to make, except that our engineers do not yet require the parts to be milled or etched. When interior defects are found in the first test piece, the rails of that position in the ingot are rejected, and the inspector passes to the next or "B" rails. If this test piece also shows interior defects, he passes to the third set or "C" rails, and if they, too, are defective, the rest of the heat is also rejected. In this way we have a graduated examination for discard which is valuable to the manufacturer as well as to the purchaser, for it prevents the waste of some good material which would be cut off by an arbitrary discard. The worst feature of a standard discard is, however, that the amount usually talked of is not deep enough to insure the removal of all the unsound material at some mills.

Mr. Andrew Lamberton, commenting upon Dr. Puppe's paper, stated that the carrying capacity of railways in the United States had increased nearly five times, and speeds had been nearly doubled, but the weight of the rails had not been increased in anything like proportion, and he did not think it fair, therefore, to blame the steel makers for failures under those conditions. We know this statement not to be exact, because the weight and strength of rail have kept pace with the increase in loads to be carried, but it is undeniable that the service is now more severe.

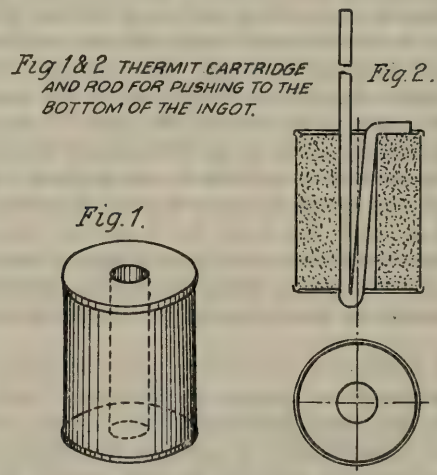
He believed that the section had a great deal to do in the matter, and it was obvious to him that, in a bull-head rail there was a better distribution of metal than in the flat-bottomed section. The cooling was more equal and the internal strains were better relieved than in the flat-bottomed section, in which the perimetrical length was greater with a small internal mass. He admitted, however, that the bull-head rail had its disadvantages, in that it was more difficult to lay and maintain and did not, perhaps, afford such smooth running as the flat-bottomed section.

Mr. Lamberton does not seem to be aware of the thickening of the base of American rails so that the metal in the head and base are practically equalized.

At this same Autumn Session of the Iron and Steel Institute, which seems to have been replete with information of interest to American railway engineers, Dr. Hans Goldschmidt, of Essen, Germany, described the use of Thermit for obtaining sound steel ingots, and his paper has been reproduced in the number of "Engineering" mentioned above.

He also stated that the question of prevention of piping in ingots is one that has always occupied the attention of metallurgists, and among their remedies the use of Thermit was long ago recommended, but its application was faulty and the method fell into disuse for a long time.

Laterally, however, a new and very successful improvement of that old process has been made, which he considers efficacious, especially in the treatment of non-siliconised steel; i. e., steel to which no silicon addition has been made, either in the furnace or in the ladle. "A cartridge, consisting of a sheet-iron box, illustrated in Fig. 1, with Thermit of proper capacity and an iron rod, illustrated in Fig. 2, by the aid of which the



box is thrust down into the molten metal, is quickly plunged right to the bottom of the ingot before solidification has begun to set in; i. e., before any of the defects generally arising have had time to take effect. The reaction immediately causes an energetic ebullition of the liquid contents of the ingot-mould, and the gases which have just begun to separate out are violently expelled, or, if the charge has not been siliconised, the bubbling of the metal due to the disengagement of the gas is incidentally checked, but (still quoting from 'Engineering') the most noticeable feature is the sinking down of the liquid metal in the mould by more than a hand's breadth as soon as the reaction is complete, and the density of the material is increased by an amount corresponding to

this reduction of volume. Further metal is then poured in from the ladle, until the level of the ingot is restored, and the ingot, if of non-siliconised steel, is then covered with an iron plate in the usual way.

"The violent frothing up, due to the reaction of Thermit, has other good effects, for the segregation already accumulating in the center is driven upwards, and the further formation of segregates prevented."

The method seems to have been particularly effective for the treatment of ingots intended for rolling into plates, and the principal advantage is that due to economy in rejections.

"Further advantages are that the quality of the plates produced is much improved, and, in particular, the strength in different parts of the plate is much more uniform, this being due to the prevention of segregation. Added to this there is also the capability of increasing the output without injuring the plant, and the quantity of waste is much reduced. The working of the rolling mill proceeds with greater regularity owing to the reduction of the number of wasters to a minimum."

Another important point is that no special apparatus other than that illustrated in Figs. 1 and 2 is necessary.

The following, taken from "Engineering," is a more exact description of the method of carrying out the process on ingots of non-siliconised material:

"The filling of the ingot-mould is effected in the usual way, either by direct pouring into each mould from above, or filling a number of moulds simultaneously by bottom pouring. After filling, the moulds are left undisturbed until the crust, which starts from the sides of the mould, has spread some little way inwards. This crust gives an indication of the progress of cooling, and hence of the right moment at which to introduce the Thermit cartridges. The width which the crust should be allowed to attain depends, of course, upon the size of the ingot, and is a matter that can only be judged by experience. The Thermit cartridge is preheated, and by means of the rod is thrust vertically down to the bottom of the ingot mould, and is held there until the reaction is complete, the rod being then withdrawn. . . . If the operation is performed at the right moment the surface of the ingot sinks down at once by several inches or more directly the boiling ceases. More metal is then poured in at the top until the surface is again restored to the original level, where the crust first began to form, and an iron plate is then lightly placed on the metal in the usual way and then covered up with sand.

"The amount by which the molten metal sinks down differs in different ingots, even in those cast from the same heat. It depends upon the degree of piping or on the size of blowholes which may be forming within the metal. The density of the ingot is, of course, greater by the amount that the metal sinks down. . . . The process is actually nothing less than a stirring-up process; that is to say, a purely mechanical and not a thermal one. Since the weight of Thermit required for a 1-ton ingot is only a little over 1 lb., the rise of temperature is practically nil. At the bottom of the liquid metal, within a limited region only, an in-

crease in temperature occurs, causing an energetic agitation of the highly-heated particles, by means of which a current is produced."

The process has already been adopted at various works with success, and on a large scale. The certainty of being able to produce sound ingots with a very small proportion of discard makes it probable that in future ingots of large size only will be cast, from which small-size plates will be rolled.

In view of the interest aroused at the recent Leeds meeting of the Iron and Steel Institute in Sir Robert Hadfield's papers regarding "A Method of Producing Sound Ingots" and "A New Method of Revealing Segregation in Steel Ingots," the following information with regard to the excellent results obtained as regards (*a*) obtaining sound steel, (*b*) avoiding segregation and (*c*) reducing waste, will be of interest.

Quite unknown to Sir Robert Hadfield, the well-known French metallurgist, Monsieur G. Charpy, of the Cie. des Forges et Acieries de Chatillon-Commentry et Neuves-Maisons, Montluçon (Allier), after reading the papers above mentioned, decided to test the methods for himself, and proceeded to make an ingot of comparatively large size, weighing about 25 tons.

The photograph and sketches accompanying this note show the results obtained.

M. Charpy stated that the Hadfield method of feeding the upper portion of the ingot in the special manner described in the papers above mentioned, namely, sand head, air blast, charcoal and insulating layer of slag, appeared to him to constitute a particularly simple and practical solution of the problem met with in steel manufacture, and to overcome the difficulties met with as regards piping, also reduce segregation and avoid the large percentage of waste material.

Fig. 3 represents a photograph taken by M. Charpy of the upper part of an ingot weighing 25 tons. This ingot had been treated by the Hadfield method, its composition being

C.	S.	P.	Mn.
0.40	0.02	0.04	0.45 per cent.

The material also contained a small percentage of nickel.

Fig. 3 shows the satisfactory nature of the method. The portion of the ingot shown in the photograph represents about one-fourth of its total length. M. Charpy found that in order to eliminate all faults and sponginess in the ingot in question, it was only necessary to cut off about 12 in. to 12½ in. from the upper part, in other words, about one-twentieth of the ingot, as against one-third which is the proportion of discard ordinarily required.

Moreover, the analyses taken of the material at different parts of the ingot showed this is free from segregation.

Fig. 3 shows section of the upper portion of the 25-ton ingot described above. The waste or unsound material in this ingot is only about 5 per cent.

Fig. 4 shows the parts from which the analyses given in table "A" were taken.

Drillings were taken on the center line at the different parts shown, commencing at the top, marked "A," also at the other parts as lettered.

It will therefore be seen that by the Hadfield method there is obtained sound steel, with but little segregation. There is also very much reduced loss or waste of material, all three important advantages in the economical production of sound steel. It is also proved that by the method not only smaller ingots, such as used in rail manufacture, but also ingots of the largest size can be satisfactorily produced with great economy in cost. The waste and segregated material in this ingot only amounts to about 5 per cent. of the total weight.

FIG. 3.

Two very important details of steel manufacture have been described in the above papers: First, the making of sound ingots, and second, the rapid reduction of the blooms in American mills. Both of these matters are receiving earnest attention on the part of the Rail Committee, and it is hoped that the rail manufacturers are making an equally earnest study, as the solution of the first may remove the question of discard from the realm of discussion. Great hope seems to be held out by the manufacturers of steel, through the papers just quoted above and through the work of the Standard Steel Works Company, described by Mr. Wickhorst in Appendix "D," that better methods for making sounder ingots are feasible, and we hope, therefore, that they will ultimately find their way universally into the manufacture of rail steel.

Three entirely different methods for making sound ingots are brought forward, those of Sir Robert Hadfield, Mr. Benjamin Talbot, and Dr. Hans Goldschmidt, and all have been successfully used in the manufac-

ture of steel. They have accomplished the object for which they were devised fairly well, and it would seem, therefore, that the American manufacturer should either devise something better, make use of the existing method best suited for the object sought, or prove those now in use to be impracticable.

25-TON INGOT—UPPER PART.

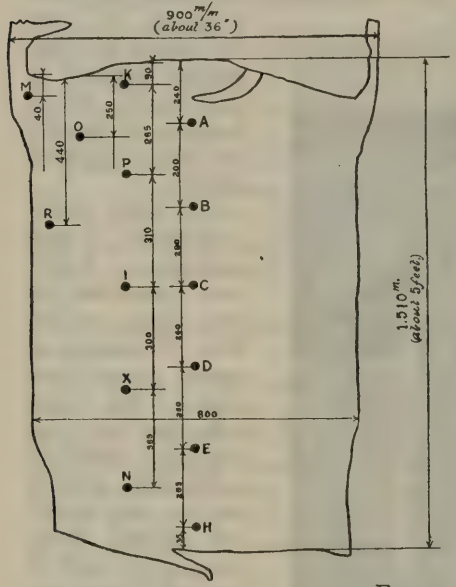


FIG 4.

TABLE "A."

PORTION DRILLED	S. %	P. %
A	0.016	0.043
B	0.018	0.041
C	0.028	0.043
D	0.024	0.042
E	0.021	0.039
H	0.020	0.043
I	0.020	0.039
K	0.012	0.044
M	0.018	0.039
N	0.017	0.039
O	0.026	0.044
P	0.028	0.045
R	0.015	0.038
X	0.015	0.038

Fig. 5 shows the dimensions of the 25-ton ingot referred to.

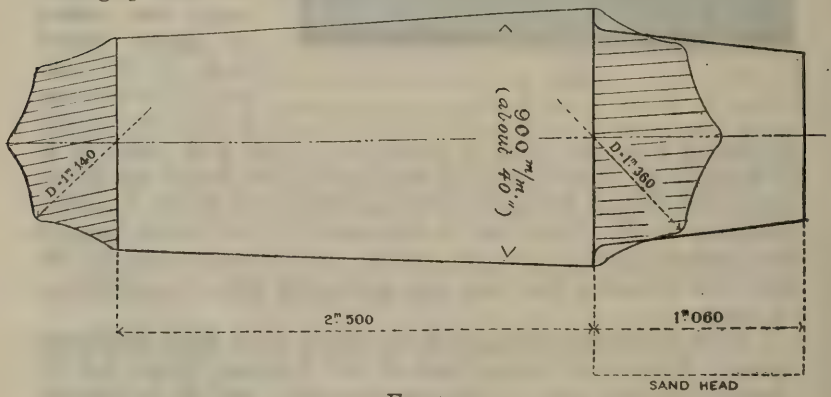


FIG 5.

Appendix L.

INFLUENCE OF SILICON ON OPEN-HEARTH INGOTS AND RAILS.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report covers an investigation concerning the influence of silicon in basic open-hearth steel ingots and rails. It was desired to have a series of ingots and a series of rails all of the same composition except to have the silicon vary from about .10 to .50 per cent. in the various members of the series. From a heat of open-hearth steel ten ingots were used for this test, five for splitting open and chemical survey and the other five for rolling into rail, which were used for drop tests, slow bending tests, flange tests and tensile tests. It was desired to have two ingots of each of the following silicons: .10 per cent., .20 per cent., .30 per cent., .40 per cent. and .50 per cent., one for direct examination and the other for test after rolling into rail, as explained above. The lowest silicon was the natural silicon of the heat and the others were obtained by additions to the molds of finely crushed 50 per cent. ferro-silicon while pouring the steel. The ferro-silicon was sized by passing through a No. 8 sieve (8 meshes to the inch) and being retained on a No. 20 sieve (20 meshes to the inch). This work was done at Gary, Ind., at the works of the Illinois Steel Company, who kindly furnished all the material and facilities for making the investigation.

MANUFACTURE.

The steel was basic open-hearth steel, heat number 54304, made June 22, 1912. Hot blast furnace iron from the mixer, some cold blast furnace iron, scrap steel, ore and limestone were charged into the furnace, melted in the bath to about .80 or .90 per cent carbon (by fracture), 3,000 lbs. of ore added and the bath dropped in carbon to about .15 per cent. (by fracture). Then 25,300 lbs. of hot blast furnace iron were added into the furnace, with 300 lbs. of 80 per cent. ferro-manganese. The heat was tapped and 50 per cent. ferro-silicon and the balance of

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the ferro-manganese were added to the ladle. The amounts of the various materials used are shown in table 1:

TABLE 1—HEAT CHARGES.

Liquid blast furnace iron	92,800 lbs.
Cold blast furnace iron	11,000 lbs.
Scrap steel	66,600 lbs.
Ore, charged	7,500 lbs.
Ore, added to bath	3,000 lbs.
Limestone	25,000 lbs.
Fluorspar	1,000 lbs.
Recarburizer, liquid iron	25,300 lbs.
Ferro-manganese, in bath	300 lbs.
Ferro-manganese, in ladle	1,200 lbs.
Ferro-silicon, in ladle	275 lbs.

The steel was tapped into a large ladle, from which it was poured into molds. The molds were about 20x24 ins. at the bottom and tapered smaller ¼ in. per foot of height. The experimental ingots were poured to a height of 63 in., while the regular ingots were poured to a height of about 69 in., and the heat made a total of 22 ingots. Ingots No. 2 to No. 12, inclusive, were used for this investigation, and during their pouring 50 per cent. cold ferro-silicon was added in amounts shown in table 2. These ingots were given test numbers 1 to 10 in consecutive order.

TABLE 2—FERRO-SILICON ADDITIONS.

Ingot Numbers	Ferro-Silicon
1 and 2	None
3 and 4	14.5 lbs. each
5 and 6	29.0 lbs. each
7 and 8	43.5 lbs. each
9 and 10	58.0 lbs. each

The ferro-silicon showed a content of 50.1 per cent. silicon on analysis. As already explained, the ferro-silicon was sized so as to pass a No. 8 sieve and be retained on a No. 20 sieve, and was added while the pouring progressed, so as to be all in the mold when about two-thirds of the ingot had been poured. All the ingots set with flat tops. The molds were plain iron molds and no covering was used on the ingot after pouring. The stools were covered with a clay wash, but nothing was used in the molds. Ingots 1, 3, 5, 7 and 9 were allowed to cool down direct without soaking and used for splitting and chemical survey, but ingots 2, 4, 6, 8 and 10 were soaked and rolled into rail of the 100-lb. A. S. C. E. section. (See Proceedings, American Railway Engineering and Maintenance of Way Association, 1911, vol. 12, part 2, page 145.) The furnace was tapped at 11:37 a. m., pouring into molds started at 11:50 a. m., pouring of the heat was finished at 12:18 p. m., and the ingots were stripped at

12:57 p. m. The ingots used for rails were charged into the soaking pits at 1:26 p. m. and drawn at 5:00 p. m. At the time of charging into the pits, ingot No. 7, which was one of those not put into the pits, fell off its stool onto its side on the ground. At about 3:00 p. m., ingots 1, 3, 5 and 9 were taken off their stools and placed on their sides in a pile, including No. 7, to cool.

The ladle sample taken as the heat was being poured gave the following results on analysis: C, .66; P, .024; S, .044; Mn, .89; Si, .15.

INGOTS.

As stated, one ingot of each silicon content was allowed to cool without soaking. The ingots were afterward split open on the short diameter to note their internal condition as to size and distribution of cavities, and to use for obtaining drillings with which to make chemical surveys of the ingots. The dimensions and weights of these ingots are shown in table 3.

TABLE 3—INGOTS USED TO SPLIT OPEN.

Ingot No.	Si Per Cent.	Height Ins.	Bottom Dimensions	Top Dimensions	Weight Lbs.
1	.17	63	20⅛ x 24¼	18½ x 22½	7,480
3	.26	62	20⅜ x 24	18½ x 22½	7,340
5	.34	63	20⅛ x 24	18½ x 22½	7,460
7	.46	61	.... x ..	18½ x 22½	7,300
9	.52	63¼	.... x 24	18½ x 22½	7,500

Each ingot was cut in two a little to one side of the longitudinal axial plane, and then the larger part was planed down to the axial surface. The width of this surface was the short diameter of the ingot. These surfaces are shown in Figs. 1 to 5, inclusive. It will be noticed that ingot 1, with about .17 per cent. silicon, was spongy or "honeycombed" at the top end with cavities of various sizes, the sponginess at the axis extending about one-third way down the ingot. The other ingots with larger amounts of silicon were mostly free from the small holes, but contained large central cavities or "pipes," with a few large holes under the roof of the ingot. The pipes extended downward from the top about one-third of the height, and there was a slightly spongy condition at the axis extending intermittently to below the middle of the ingot.

ANALYSES OF INGOTS.

A chemical survey was made of each of the ingots by means of drillings taken as shown in Fig. 6, the drillings being taken from the halves of the ingots previously illustrated. There were five vertical rows of drillings, 15 samples per row, from one-half of the section, making a total of 75 samples from each ingot, less the number that could not be obtained due to the cavities in the ingot. On each sample, determina-

FIG. 1—INGOT 1, .17 PER CENT. SILICON.

FIG. 2—INGOT 3, .26 PER CENT. SILICON.

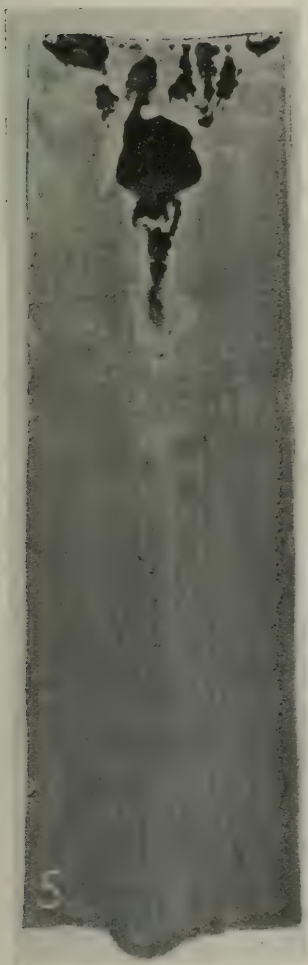


FIG. 3—INGOT 5, .34 PER CENT. SILICON.

FIG. 4—INGOT 7, .46 PER CENT. SILICON.

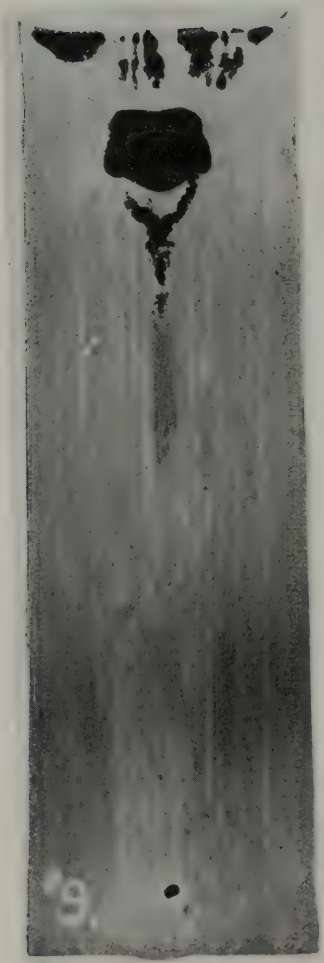


Fig. 5—Ingot 9, .52 Per Cent. Silicon.

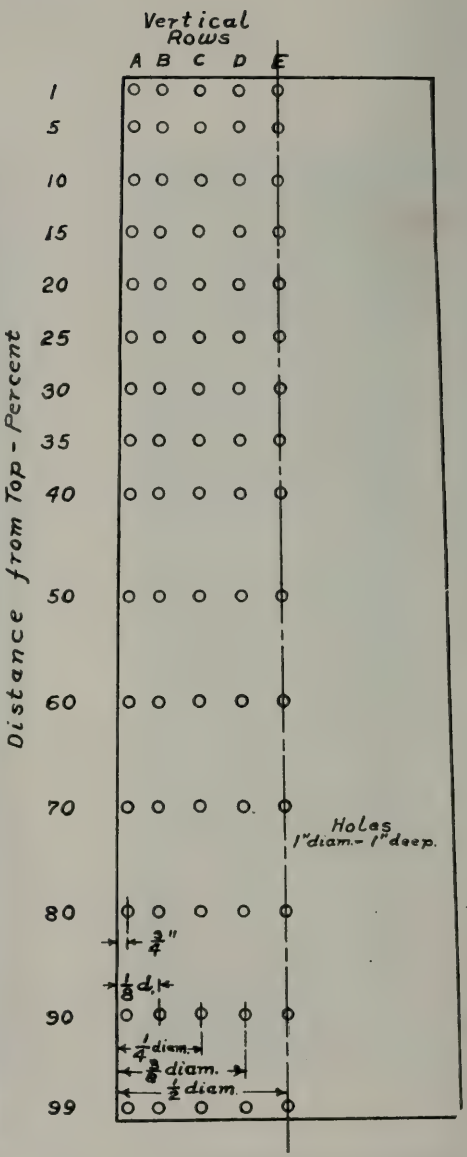


Fig. 6—Drilling Diagram for Rail Ingots.

tions were made of carbon (by combustion), phosphorus, sulphur, manganese and silicon. These analyses are shown in tables as follows:

Carbon	Tables 4 to 8, inclusive
Phosphorus	Tables 9 to 13, inclusive
Sulphur	Tables 14 to 18, inclusive
Manganese	Tables 19 to 23, inclusive
Silicon	Tables 24 to 28, inclusive

TABLE 4—CARBON IN INGOT 1.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.66	.72	.60	.57	.60
5	.68	.76	.79	.80	.82
10	.70	.70	.73	.74	.82
15	.72	.70	.73	.81	1.28
20	.74	.72	.77	.81	1.26
25	.72	.73	.75	.73	1.06
30	.74	.72	.75	.75	.86
35	.73	.73	.75	.77	.86
40	.68	.72	.75	.76	.75
50	.73	.72	.73	.74	.70
60	.74	.73	.74	.72	.73
70	.74	.72	.74	.70	.74
80	.74	.71	.74	.67	.73
90	.74	.73	.70	.64	.70
99	.73	.73	.74	.71	.74

TABLE 5—CARBON IN INGOT 3.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.71	..	..	..	..
5	.73	.72	..	..	..
10	.73	.75	.74	..	..
15	.74	.74	.76	..	..
20	.74	.74	.74	.88	..
25	.74	.74	.74	.88	..
30	.74	.73	.73	.81	.74
35	.74	.74	.73	.79	.74
40	.73	.74	.74	.73	.74
50	.72	.74	.74	.75	.73
60	.72	.72	.74	.75	.72
70	.74	.74	.74	.70	.68
80	.74	.74	.74	.70	.67
90	.74	.74	.74	.70	.68
99	.74	.74	.74	.73	.72

TABLE 6—CARBON IN INGOT 5.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	...	...	...	.65	.71
5	.73	.73	...	...	...
10	.74	.74	.72	...	...
15	.73	.74	.74	...	...
20	.73	.74	.74	.86	...
25	.74	.74	.73	.85	...
30	.73	.71	.74	.71	...
35	.74	.72	.75	.72	.73
40	.73	.75	.74	.77	.72
50	.74	.73	.73	.73	.70
60	.73	.73	.73	.70	.70
70	.73	.73	.74	.71	.74
80	.73	.68	.73	.67	.71
90	.73	.73	.71	.70	.70
99	.74	.73	.71	70	.72

TABLE 7—CARBON IN INGOT 7.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.74	...	...	.72	.73
5	.74	.71	.70	...	...
10	.73	.74	.74	...	...
15	.74	.74	.74	...	...
20	.73	.74	.74	.72	...
25	.71	.73	.74	.73	...
30	.74	.73	.74	.87	.78
35	.74	.73	.74	.74	.72
40	.74	.74	.70	.73	.74
50	.72	.74	.70	.73	.63
60	.74	.74	.71	.73	.74
70	.74	.74	.70	.71	.72
80	.73	.73	.74	.71	.72
90	.72	.74	.72	.69	.72
99	.72	.74	.74	.74	.74

TABLE 8—CARBON IN INGOT 9.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.73	...	...	...	...
5	.75	.74	.70	.67	.64
10	.76	.72	.67	...	...
15	.77	.70	.74	...	...
20	.75	.72	.74	.84	...
25	.76	.70	.74	.83	...
30	.75	.68	.74	.85	...

TABLE 8—CONTINUED.

Per Cent. from Top.	A.	B.	C.	D.	E.
35	.76	.71	.74	.75	.72
40	.75	.70	.74	.73	.72
50	.74	...	.74	.66	.67
60	.73	.70	.74	.71	.74
70	.74	.70	.74	.66	.67
80	.75	.73	.72	.66	.66
90	.73	.72	.69	.67	.66
99	.75	.69	.72	.72	.74

TABLE 9—PHOSPHORUS IN INGOT 1.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.018	.020	.020	.019	.022
5	.020	.025	.028	.033	.034
10	.020	.023	.026	.028	.035
15	.022	.028	.026	.032	.075
20	.022	.028	.026	.032	.069
25	.024	.023	.027	.028	.058
30	.027	.026	.024	.027	.033
35	.027	.027	.023	.029	.037
40	.026	.026	.025	.027	.028
50	.027	.027	.023	.027	.026
60	.027	.027	.027	.027	.026
70	.026	.027	.025	.023	.021
80	.027	.027	.026	.025	.028
90	.027	.027	.025	.025	.026
99	.026	.027	.025	.025	.028

TABLE 10—PHOSPHORUS IN INGOT 3.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.021	....	....	....	....
5	.027	.023	....	....	....
10	.026	.027	.020	....	....
15	.027	.025	.021	....	....
20	.026	.025	.021	.024	....
25	.027	.020	.022	.027	....
30	.026	.022	.022	.024	.025
35	.027	.026	.023	.023	.024
40	.027	.025	.023	.026	.024
50	.027	.026	.022	.027	.023
60	.026	.025	.023	.024	.025
70	.025	.026	.021	.023	.022
80	.027	.026	.023	.022	.024
90	.027	.025	.025	.023	.024
99	.026	.026	.024	.022	.024

TABLE 11—PHOSPHORUS IN INGOT 5.

Per Cent. from Top	A.	B.	C.	D.	E.
1	....	....	....	.025	....
5	.023	.023	....	....	....
10	.024	.026	.026	....	.. .
15	.025	.024	.023	....	....
20	.024	.025	.025	.026	....
25	.022	.024	.027	.033	....
30	.023	.025	.027	.031	....
35	.024	.026	.028	.032	.023
40	.025	.023	.027	.028	.025
50	.024	.024	.027	.031	.022
60	.023	.025	.025	.026	.025
70	.023	.025	.025	.024	.025
80	.025	.024	.027	.023	.024
90	.024	.026	.024	.020	.021
99	.022	.023	.027	.026	.023

TABLE 12—PHOSPHORUS IN INGOT 7.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.021	....	....	.021	.021
5	.024	.026	.020	....	....
10	.025	.027	.024	....	....
15	.026	.027	.026	....	....
20	.025	.022	.024	.023	....
25	.026	.025	.022	.027	....
30	.021	.027	.025	.024	.025
35	.025	.023	.024	.025	.022
40	.026	.027	.023	.024	.022
50	.023	.023	.025	.020	.024
60	.022	.027	.021	.023	.024
70	.023	.028	.027	.026	.023
80	.021	.025	.024	.021	.021
90	.023	.027	.023	.022	.022
99	.026	.026	.022	.021	.024

TABLE 13—PHOSPHORUS IN INGOT 9.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.023	....	....	....	....
5	.025	.025	.025	.023	.018
10	.026	.026	.025	....	....
15	.025	.026	.026	....	....
20	.023	.025	.022	.031	....
25	.023	.025	.025	.036	....
30	.027	.024	.023	.025	....

TABLE 13—CONTINUED.

Per Cent. from Top.	A.	B.	C.	D.	E.
35	.024	.026	.028	.025	.025
40	.026	.024	.028	.024	.026
50	.027	....	.025	.023	.020
60	.027	.025	.026	.025	.024
70	.027	.027	.026	.024	.024
80	.028	.026	.024	.022	.023
90	.024	.025	.024	.024	.022
99	.025	.025	.022	.024	.025

TABLE 14—SULPHUR IN INGOT 1.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.035	.032	.030	.032	.030
5	.038	.037	.036	.051	.050
10	.039	.034	.043	.044	.058
15	.042	.038	.038	.049	.128
20	.044	.043	.042	.050	.124
25	.044	.046	.042	.042	.090
30	.043	.040	.044	.040	.055
35	.043	.043	.044	.044	.060
40	.043	.046	.045	.043	.044
50	.045	.045	.046	.044	.040
60	.043	.045	.045	.044	.046
70	.042	.041	.046	.045	.042
80	.043	.045	.045	.044	.040
90	.043	.044	.042	.046	.040
99	.043	.043	.045	.045	.043

TABLE 15—SULPHUR IN INGOT 3.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.035	....	....	....	....
5	.045	.041	....	....	....
10	.041	.051	.037	....	....
15	.045	.044	.042	....	....
20	.045	.044	.043	.045	....
25	.044	.044	.044	.051	....
30	.046	.046	.041	.046	.044
35	.046	.044	.042	.045	.045
40	.046	.043	.047	.043	.042
50	.045	.042	.041	.043	.045
60	.045	.040	.042	.040	.045
70	.047	.043	.039	.044	.043
80	.046	.047	.042	.036	.040
90	.047	.047	.041	.040	.041
99	.047	.049	.045	.043	.045

TABLE 16—SULPHUR IN INGOT 5.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	....	....	....	.037	....
5	.043	.041	....	....	....
10	.044	.042	.040	....	....
15	.044	.042	.041	....	....
20	.045	.042	.041	.051	....
25	.044	.044	.042	.055	....
30	.042	.041	.042	.053	....
35	.042	.040	.040	.051	.043
40	.043	.042	.040	.049	.043
50	.044	.045	.040	.045	.043
60	.043	.040	.041	.044	.044
70	.044	.044	.041	.044	.044
80	.044	.041	.040	.042	.043
90	.044	.042	.041	.040	.044
99	.043	.045	.041	.043	.043

TABLE 17—SULPHUR IN INGOT 7.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.043	....	....	.037	.040
5	.043	.040	.037	....	....
10	.045	.042	.043	....	....
15	.046	.043	.044	....	....
20	.044	.043	.043	.052	....
25	.045	.043	.045	.062	....
30	.043	.044	.045	.057	.045
35	.044	.046	.041	.045	.043
40	.046	.046	.047	.047	.044
50	.046	.043	.040	.043	.041
60	.044	.045	.045	.045	.045
70	.042	.047	.042	.043	.041
80	.046	.042	.042	.042	.045
90	.045	.045	.041	.040	.041
99	.045	.047	.042	.046	.044

TABLE 18—SULPHUR IN INGOT 9.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.040	....	....	....	....
5	.047	.043	.036	.040	.032
10	.046	.043	.033	....	....
15	.044	.044	.043	....	....
20	.044	.045	.042	.054	....
25	.044	.044	.043	.056	....
30	.046	.043	.043	.054	....

TABLE 18—CONTINUED.

Per Cent. from Top.	A.	B.	C.	D.	E.
35	.044	.045	.042	.054	.040
40	.045	.041	.042	.044	.043
50	.045	....	.043	.040	.031
60	.043	.044	.043	.043	.040
70	.045	.045	.043	.041	.040
80	.042	.042	.042	.040	.034
90	.044	.042	.046	.042	.035
99	.044	.044	.043	.042	.040

TABLE 19—MANGANESE IN INGOT 1.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.91	.93	.87	.90	.87
5	.91	.93	.92	.94	.95
10	.93	.93	.93	.91	.91
15	.94	.94	.90	.94	1.02
20	.93	.98	.89	.94	1.02
25	.94	.94	.88	.88	1.00
30	.91	.98	.95	.91	.95
35	.93	.98	.95	.94	.96
40	.93	.98	.94	.92	.94
50	.91	.94	.94	.92	.93
60	.91	.95	.95	.94	.94
70	.92	.94	.95	.95	.90
80	.93	.94	.93	.93	.92
90	.91	.94	.94	.90	.91
99	.93	.93	.94	.92	.91

TABLE 20—MANGANESE IN INGOT 3.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.85	...	...	...	...
5	.89	.90	...	...	...
10	.89	.89	.90	...	...
15	.92	.91	.90	...	...
20	.89	.92	.91	.92	...
25	.93	.88	.89	.92	...
30	.87	.89	.87	.87	.90
35	.92	.89	.87	.90	.88
40	.92	.90	.88	.91	.87
50	.91	.88	.88	.90	.84
60	.92	.88	.92	.87	.86
70	.88	.87	.92	.89	.85
80	.88	.86	.88	.86	.87
90	.89	.87	.89	.88	.88
99	.88	.85	.88	.88	.89

TABLE 21—MANGANESE IN INGOT 5.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	...	...	...	.88	.88
5	.90	.89	...	...	...
10	.90	.89	.89	...	...
15	.90	.88	.89	...	...
20	.90	.92	.91	.92	...
25	.90	.92	.90	.90	...
30	.90	.90	.90	.94	...
35	.90	.89	.89	.94	.90
40	.90	.90	.92	.90	.90
50	.88	.88	.91	.90	.87
60	.90	.91	.88	.89	.88
70	.90	.87	.89	.90	.89
80	.90	.90	.87	.88	.88
90	.90	.88	.88	.87	.90
99	.90	.90	.90	.91	.90

TABLE 22—MANGANESE IN INGOT 7.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.89	...	...	.88	.89
5	.88	.86	.90	...	...
10	.90	.89	.89	...	...
15	.86	.88	.87	...	...
20	.89	.90	.93	.92	.89
25	.91	.87	.93	.93	...
30	.87	.90	.90	.91	.92
35	.88	.86	.91	.87	.87
40	.88	.87	.90	.89	.89
50	.91	.86	.90	.87	.88
60	.87	.86	.90	.89	.89
70	.87	.87	.92	.88	.89
80	.87	.89	.90	.88	.88
90	.91	.87	.90	.88	.88
99	.89	.90	.90	.91	.91

TABLE 23—MANGANESE IN INGOT 9.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.88	...	...	...	...
5	.89	.87	.84	.86	.85
10	.89	.87	.84	...	...
15	.90	.86	.87	...	...
20	.90	.87	.89	.94	...
25	.90	.87	.86	.93	...
30	.90	.88	.86	.92	...

TABLE 23—CONTINUED.

Per Cent. from Top.	A.	B.	C.	D.	E.
35	.90	.88	.89	.89	.88
40	.91	.90	.90	.86	.88
50	.90	...	.87	.89	.86
60	.90	.90	.90	.88	.87
70	.90	.87	.89	.87	.86
80	.89	.88	.89	.86	.84
90	.91	.90	.89	.89	.85
99	.89	.90	.90	.89	.87

TABLE 24—SILICON IN INGOT 1.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.11	.14	.18	.19	.16
5	.15	.13	.18	.26	.18
10	.15	.14	.17	.17	.18
15	.18	.15	.18	.16	.19
20	.18	.14	.18	.18	.20
25	.18	.14	.18	.15	.19
30	.18	.14	.18	.17	.19
35	.18	.15	.17	.17	.20
40	.18	.12	.18	.15	.19
50	.18	.13	.17	.18	.18
60	.18	.12	.18	.18	.18
70	.17	.13	.18	.18	.17
80	.16	.17	.18	.18	.15
90	.16	.14	.18	.18	.17
99	.17	.15	.18	.18	.20

TABLE 25—SILICON IN INGOT 3.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.27	...	...	...	...
5	.24	.25	...	...	...
10	.23	.24	.24	...	...
15	.24	.25	.24	...	...
20	.24	.25	.24	.24	...
25	.27	.23	.26	.22	...
30	.22	.26	.24	.25	.24
35	.25	.23	.26	.23	.23
40	.24	.25	.23	.24	.23
50	.26	.25	.26	.23	.22
60	.25	.26	.27	.24	.22
70	.26	.23	.22	.22	.22
80	.26	.26	.22	.23	.23
90	.30	.26	.23	.26	.23
99	.25	.25	.25	.27	.23

TABLE 26—SILICON IN INGOT 5.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	...	...	...	.32	...
5	.32	.32	...	...	...
10	.35	.33	.33	...	...
15	.33	.34	.33	...	...
20	.35	.32	.30	.34	...
25	.33	.33	.33	.38	...
30	.31	.35	.36	.33	...
35	.35	.32	.35	.38	.33
40	.35	.35	.33	.34	.34
50	.30	.34	.32	.37	.35
60	.33	.37	.36	.31	.32
70	.36	.34	.36	.32	.34
80	.33	.34	.37	.35	.32
90	.35	.32	.33	.35	.32
99	.35	.36	.33	.35	.36

TABLE 27—SILICON IN INGOT 7.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.44	...	...	.46	.43
5	.42	.44	...	...	...
10	.42	.45	.42	...	...
15	.41	.44	.43	...	...
20	.46	.47	.45	.48	...
25	.47	.47	.43	.49	...
30	.45	.46	.42	.45	.44
35	.47	.47	.44	.47	.42
40	.45	.43	.45	.49	.43
50	.47	.47	.47	.45	.46
60	.43	.46	.45	.43	.44
70	.46	.47	.44	.45	.44
80	.47	.44	.48	.47	.44
90	.48	.43	.47	.48	.44
99	.46	.46	.48	.48	.45

TABLE 28—SILICON IN INGOT 9.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.52	...	...	...	...
5	.53	.51	.51	.53	.51
10	.50	.51	.51	...	...
15	.50	.50	.51	...	...
20	.51	.52	.53	.55	...
25	.53	.51	.51	.53	...
30	.51	.53	.51	.52	...

TABLE 28—CONTINUED.

Per Cent. from Top.	A.	B.	C.	D.	E.
35	.50	.51	.52	.51	.50
40	.52	.52	.52	.51	.50
50	.51	...	.50	.50	.51
60	.53	.51	.53	.51	.53
70	.54	.51	.53	.53	.50
80	.53	.50	.53	.50	.51
90	.53	.51	.50	.52	.51
99	.53	.51	.51	.52	.50

Probably the samples from the wall of the lower half of the ingot and those along the bottom of the ingot represent fairly closely the average steel of the ingot, and I give in table 29 the averages for the five ingots and also the heat analysis. The average for each ingot is the average of the six samples from the wall of the lower half of the ingot and the four samples from the bottom, each average thus being a total of ten samples.

TABLE 29—AVERAGE STEEL IN INGOTS.

Ingot number.	C.	P.	S.	Mn.	Si.
1	.73	.027	.043	.92	.17
3	.73	.025	.046	.89	.26
5	.73	.024	.043	.91	.34
7	.73	.023	.045	.89	.46
9	.73	.025	.043	.90	.52
General average	.73	.025	.044	.90	...
Ladle test	.66	.024	.044	.89	.15

It will be noted that the composition of the steel as determined by the analyses of the ingots agrees well with the ladle analysis representing the heat, except in the case of carbon, which showed up considerably lower in the ladle analysis. The ladle analysis showed .66 per cent. carbon and the analyses of the ingots showed .73 per cent.

At any given distance from the top of the ingot the extreme variations in composition are in general shown by the axis and the walls of the ingot and to show conveniently the changes from the top to the bottom of the ingot, the carbon, phosphorus and sulphur are respectively plotted in figures 7, 8 and 9, each figure showing the one element in the five ingots. The distance from the top of the ingot, in per cent. of the height, is shown horizontally and the amount of the element is shown vertically. Where samples could not be obtained from the axis on account of cavities, the results from row D were, in general, taken as representing the axis. This was also done in a few other cases from the upper part of the ingot in order to better show the maximum segregation.

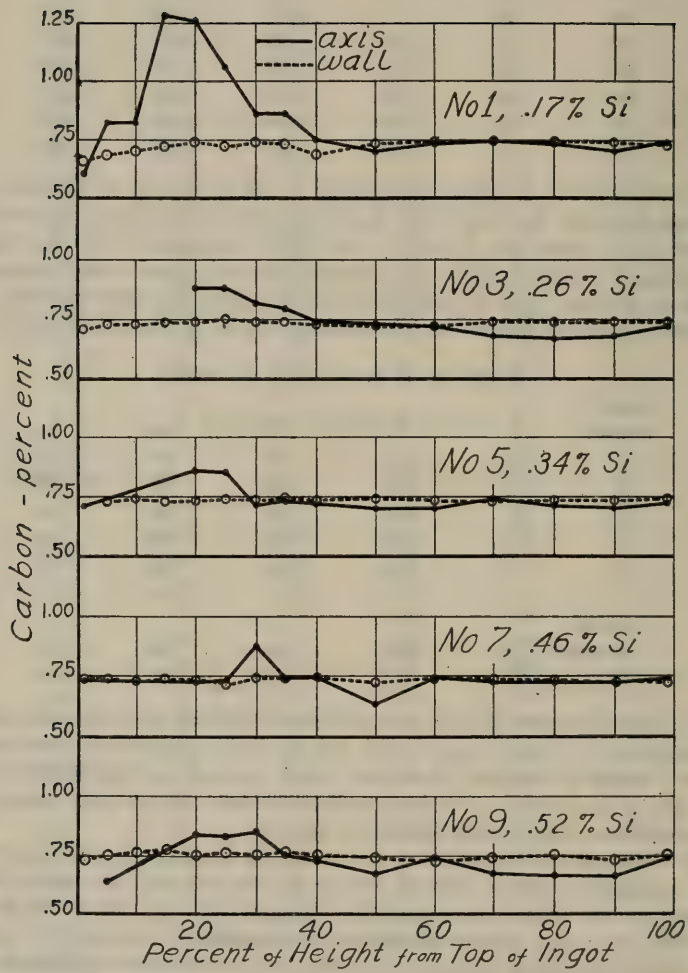


FIG. 7—CARBON DIAGRAMS OF THE AXES AND WALLS OF THE FIVE INGOTS.

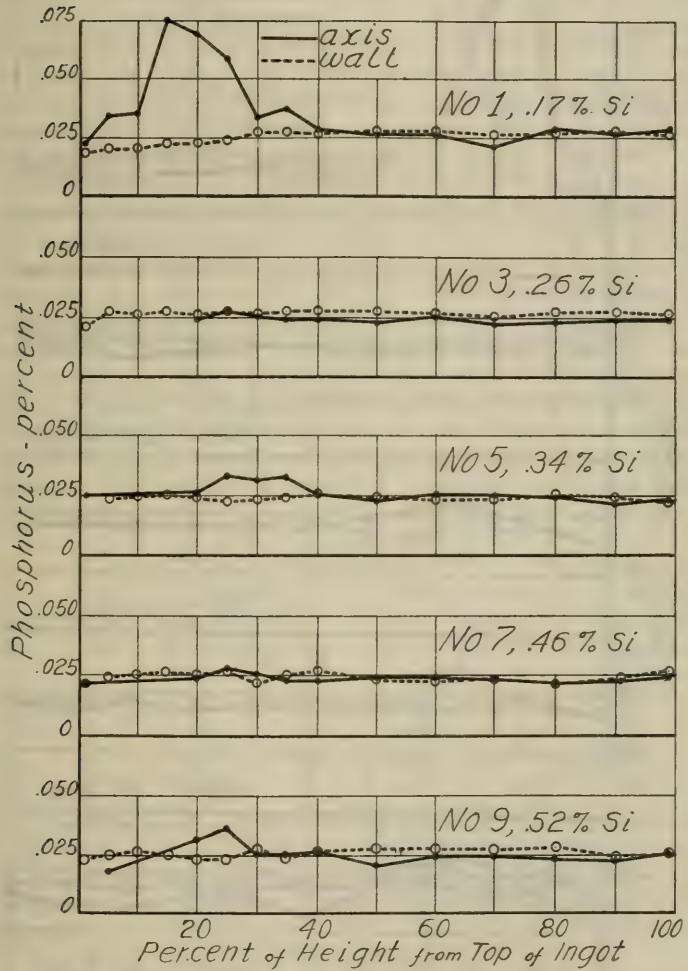


FIG. 8—PHOSPHORUS DIAGRAMS OF THE AXES AND WALLS OF THE FIVE INGOTS.

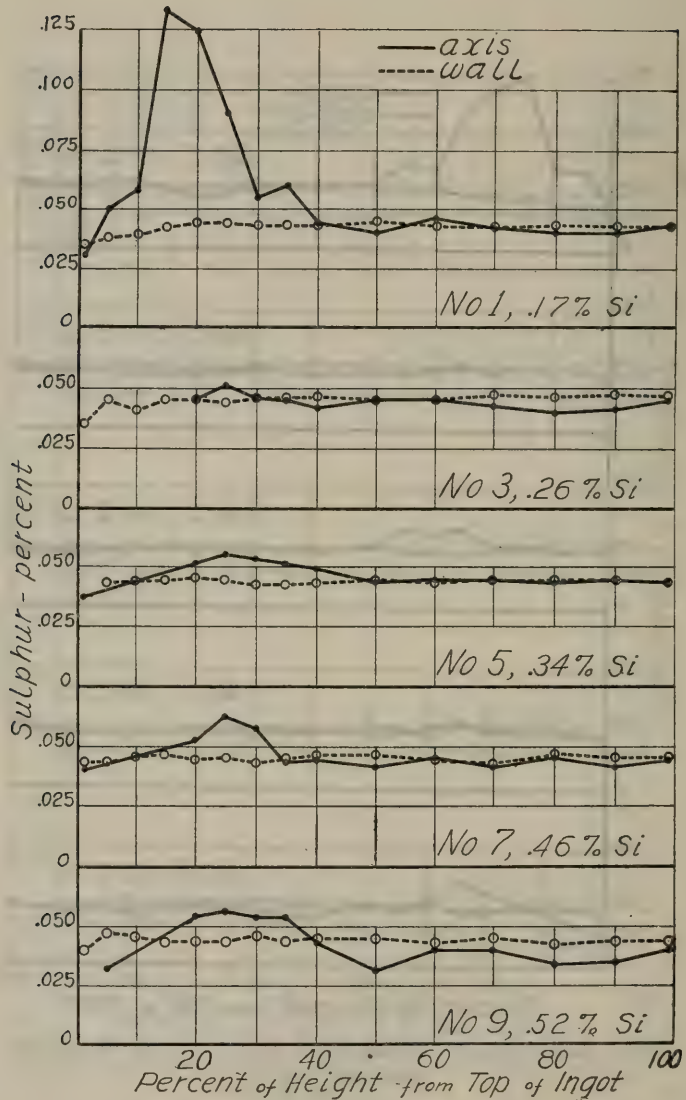


FIG. 9—SULPHUR DIAGRAMS OF THE AXES AND WALLS OF THE FIVE INGOTS.

It will be noticed that ingot 1 with .17 per cent. silicon was low in carbon, phosphorus and sulphur at the axis at the top of the ingot, these elements being in this location below the average content of the ingot, but they rapidly increased at the axis downward of the ingot so that there was soon a considerable segregation of these elements, reaching a maximum at about 15 or 20 per cent. of the height from the top of the ingot. In the lower part of this ingot the axis showed about the average composition or a little below. The walls of this ingot showed about the average composition, except for the upper 10 or 15 per cent. of the height where there was some negative segregation.

The other ingots, containing .26 per cent. or more of silicon, had a much more uniform distribution of the elements. There was a mild positive segregation at the axis in the region from about 20 to 30 per cent. down from the top and some negative segregation in the lower part of the ingot. The walls were of fairly uniform composition throughout the height of the ingot. It will thus be seen that *silicon in amounts of .26 per cent. or over was attended with less segregation in the interior and upper part of the ingot than occurred in the open-hearth steel with .17 per cent. silicon.* Possibly the tendency to segregate may have been about the same but on account of the large pipe the metalloids could not concentrate in so small a volume. The maximum amounts of positive segregation found at the axes of the various ingots and the per cents. of increase above the average contents of the five ingots are shown in table 30.

TABLE 30—SEGREGATION AT AXES OF INGOTS.

		Carbon.		Phosphorus.		Sulphur.	
Ingot No.	Per ct. Si.	Max. amt.	Increase per cent.	Max. amt.	Increase per cent.	Max. amt.	Increase per cent.
1	.17	1.28	75	.075	200	.128	191
3	.26	.88	21	.027	8	.051	16
5	.34	.86	18	.033	32	.055	25
7	.46	.87	19	.027	8	.062	41
9	.52	.84	15	.036	44	.056	27

It will be noted again that the ingot with .17 per cent. silicon showed considerable segregation and that those with .26 per cent. or more of silicon showed very much less. An examination of the tables shows that manganese segregated only a little and silicon showed no noticeable segregation.

RAILS.

As explained, ingots 2, 4, 6, 8 and 10, after soaking, were rolled into 100-lb. rails of the A. S. C. E. section and the rail-bars were numbered respectively 1, 2, 3, 4 and 5. The ingots were bloomed to 8x8 inches in 9 passes and formed into rail in 9 more passes, making a total of 18 passes from the ingot to the rail. Only such croppings were made from the ends of the blooms as were necessary to permit of the bars going through the rolls. The blooms were cut in two and rolled into rail-bars of three

rails each. The weights of the bloom and rail crops and the rails are shown in table 31.

TABLE 31—WEIGHTS OF CROPPINGS AND RAILS.

	1.	2.	3.	4.	5.
Bloom crop, top	155	178	177	196	248
Rail crop, top	123	93	82	75	16
Three rails, A, B, and C	3,300	3,300	3,300	3,300	3,300
Rail crop, 1st intermediate	.....	49	46	50	28
Rail crop, 2d intermediate	66	128	95	80	29
Three rails, D, E and F	3,300	3,300	3,300	3,300	3,300
Rail crop, bottom	52	52	46	36	.....
Bloom crop, bottom	325	210	290	248	242
Total ingot	7,321	7,310	7,336	7,285	7,163

Rail C of rail-bar 1 and rail F or rail-bar 5 were not quite full length of 33 ft., but the shortage was only small and no correction was made in the above weights.

Samples for analysis as representing the averages of the rail-bars were taken from near the top end of the D rail of each rail-bar with a ⅝-inch drill by drilling deeply into the top of the head. The samples were taken from the D 2 pieces used for base tests, and the results of analysis are shown in table 32.

TABLE 32—ANALYSES OF RAILS.

Sample.	C.	P.	S.	Mn.	Si.
1 D 2	.72	.028	.046	.92	.15
2 D 2	.70	.027	.044	.94	.25
3 D 2	.68	.027	.043	.89	.33
4 D 2	.67	.028	.042	.90	.45
5 D 2	.71	.026	.044	.90	.54
Average	.70	.027	.044	.91	

The entire rail-bar of each of the ingots used for rails was used for drop tests, longitudinal bending tests in the test machine, flange tests and tensile tests, and was divided into units of one-half rail length or 16½ ft. each. The pieces cut from each rail and the tests made are shown in table 33.

TABLE 33—TESTS FROM EACH RAIL.

No. 1—4½ in. for tensile test.
No. 2—2 ft. 7½ in. for flange test.
No. 3—4 ft. for drop test with head in tension.
No. 4—4 ft. for drop test with base in tension.
No. 5—5½ ft. for longitudinal bending test in test machine, with head in tension.
No. 6—4½ in. for tensile tests.
No. 7—2 ft. 7½ in. for flange tests.

No. 8—4 ft. for drop test with head in tension.
No. 9—4 ft. for drop test with base in tension.
No. 10—5½ ft. for longitudinal bending test in test machine, with base in tension.

The distance of each test piece from the top of the ingot, expressed in lbs. and in per cent. of weight, is shown in tables 34 to 38 inclusive. This distance is figured to the middle of the test piece.

TABLE 34—TEST PIECES RAIL-BAR 1—DISTANCE FROM TOP OF INGOT.

Test Piece	Pounds	Per Cent	Test Piece	Pounds	Per Cent	Test Piece	Pounds	Per Cent
1A1	285	4.0	1B1	1,385	18.9	1C1	2,485	34.0
2	336	4.6	2	1,436	19.6	2	2,536	34.6
3	445	6.1	3	1,545	21.1	3	2,645	36.1
4	578	7.9	4	1,678	22.9	4	2,778	37.9
5	736	10.0	5	1,836	25.1	5	2,936	40.1
6	835	11.4	6	1,935	26.4	6	3,035	41.5
7	886	12.1	7	1,986	27.1	7	3,086	42.2
8	995	13.6	8	2,095	28.6	8	3,195	43.6
9	1,128	15.4	9	2,228	30.4	9	3,328	45.5
10	1,286	17.6	10	2,386	32.6	10	3,486	47.6
1D1	3,651	49.8	1E1	4,751	65.0	1F1	5,851	80.0
2	3,702	50.6	2	4,802	65.7	2	5,902	80.7
3	3,811	52.1	3	4,911	67.1	3	6,011	82.1
4	3,944	53.9	4	5,044	68.9	4	6,144	83.9
5	4,102	56.0	5	5,202	71.1	5	6,302	86.1
6	4,201	57.4	6	5,301	72.5	6	6,401	87.5
7	4,252	58.1	7	5,352	73.2	7	6,452	88.2
8	4,361	59.6	8	5,461	74.6	8	6,561	89.7
9	4,494	61.4	9	5,594	76.5	9	6,694	91.5
10	4,652	63.6	10	5,752	78.7	10	6,852	93.6

TABLE 35—TEST PIECES RAIL-BAR 2—DISTANCE FROM TOP OF INGOT.

Test Piece	Pounds	Per Cent	Test Piece	Pounds	Per Cent	Test Piece	Pounds	Per Cent
2A1	278	3.8	2B1	1,378	18.8	2C1	2,478	33.9
2	329	4.5	2	1,429	19.5	2	2,529	34.6
3	438	6.0	3	1,538	21.0	3	2,638	36.1
4	571	7.8	4	1,671	22.8	4	2,771	37.9
5	729	10.0	5	1,829	25.0	5	2,929	40.1
6	828	11.3	6	1,928	26.4	6	3,028	41.5
7	879	12.0	7	1,979	27.1	7	3,079	42.2
8	988	13.5	8	2,088	28.6	8	3,188	43.6
9	1,121	15.3	9	2,221	30.4	9	3,321	45.5
10	1,279	17.5	10	2,379	32.5	10	3,479	47.6
2D1	3,755	51.4	2E1	4,855	66.5	2F1	5,955	81.5
2	3,806	52.1	2	4,906	67.2	2	6,006	82.2
3	3,915	53.5	3	5,015	68.6	3	6,115	83.7
4	4,048	55.3	4	5,148	70.4	4	6,248	85.5
5	4,206	57.5	5	5,306	72.5	5	6,406	87.7
6	4,305	58.9	6	5,405	74.0	6	6,505	89.0
7	4,356	59.6	7	5,456	74.7	7	6,556	89.8
8	4,465	61.1	8	5,565	76.2	8	6,665	91.1
9	4,598	62.9	9	5,698	78.0	9	6,798	93.0
10	4,756	65.1	10	5,856	80.2	10	6,956	95.3

TABLE 36—TEST PIECES RAIL-BAR 3—DISTANCE FROM TOP OF INGOT.

Test Piece	Pounds	Per Cent	Test Piece	Pounds	Per Cent	Test Piece	Pounds	Per Cent
3A1	266	3.6	3B1	1,366	18.6	3C1	2,466	33.7
2	317	4.3	2	1,417	19.3	2	2,517	34.3
3	426	5.8	3	1,526	20.8	3	2,626	35.8
4	559	7.6	4	1,659	22.6	4	2,759	37.6
5	717	9.8	5	1,817	24.8	5	2,917	39.8
6	816	11.1	6	1,916	26.1	6	3,016	41.1
7	867	11.8	7	1,967	26.8	7	3,067	41.8
8	976	13.3	8	2,076	28.3	8	3,176	43.3
9	1,109	15.1	9	2,209	30.1	9	3,309	45.1
10	1,267	17.3	10	2,367	32.3	10	3,467	47.3
3D1	3,707	50.6	3E1	4,807	65.6	3F1	5,907	80.6
2	3,758	51.3	2	4,858	66.3	2	5,958	81.3
3	3,867	52.7	3	4,967	67.8	3	6,067	82.8
4	4,000	54.6	4	5,100	69.6	4	6,200	84.6
5	4,158	56.8	5	5,258	71.8	5	6,358	86.8
6	4,257	58.1	6	5,357	73.1	6	6,457	88.1
7	4,308	58.8	7	5,408	73.8	7	6,508	88.9
8	4,417	60.3	8	5,517	75.4	8	6,617	90.3
9	4,550	62.1	9	5,650	77.1	9	6,750	92.1
10	4,708	64.3	10	5,808	79.3	10	6,908	94.4

TABLE 37—TEST-PIECES RAIL-BAR 4—DISTANCE FROM TOP OF INGOT.

Test Piece	Pounds	Per Cent	Test Piece	Pounds	Per Cent	Test Piece	Pounds	Per Cent
4A1	278	3.8	4B1	1,378	18.9	4C1	2,478	34.0
2	329	4.5	2	1,429	19.6	2	2,529	34.7
3	438	6.0	3	1,538	21.1	3	2,638	36.2
4	571	7.8	4	1,671	22.9	4	2,771	38.0
5	729	10.0	5	1,829	25.1	5	2,929	40.2
6	828	11.4	6	1,928	26.5	6	3,028	41.6
7	879	12.1	7	1,979	27.2	7	3,079	42.2
8	988	13.6	8	2,088	28.7	8	3,188	43.8
9	1,121	15.3	9	2,221	30.5	9	3,321	45.6
10	1,279	17.5	10	2,379	32.6	10	3,479	47.7
4D1	3,708	50.9	4E1	4,808	66.0	4F1	5,908	81.1
2	3,759	51.6	2	4,859	66.7	2	5,959	81.8
3	3,868	53.1	3	4,968	68.2	3	6,068	83.3
4	4,001	55.0	4	5,101	70.0	4	6,201	85.2
5	4,159	57.1	5	5,259	72.2	5	6,359	87.3
6	4,258	58.5	6	5,358	73.6	6	6,458	88.7
7	4,309	59.2	7	5,409	74.3	7	6,509	89.4
8	4,418	60.7	8	5,518	75.8	8	6,618	90.9
9	4,551	62.5	9	5,651	77.6	9	6,751	92.7
10	4,709	64.6	10	5,809	79.8	10	6,909	95.0

TABLE 38—TEST PIECES RAIL-BAR 5—DISTANCE FROM TOP OF INGOT.

Test Piece	Pounds	Per Cent	Test Piece	Pounds	Per Cent	Test Piece	Pounds	Per Cent
5A1	271	3.8	5B1	1,371	19.2	5C1	2,471	34.5
2	322	4.5	2	1,422	19.9	2	2,522	35.2
3	431	6.0	3	1,531	21.4	3	2,631	36.8
4	564	7.9	4	1,664	23.2	4	2,764	38.6
5	722	10.1	5	1,822	25.2	5	2,922	40.8
6	821	11.5	6	1,921	26.8	6	3,021	42.2
7	872	12.2	7	1,972	27.6	7	3,072	42.9
8	981	13.8	8	2,081	29.0	8	3,181	44.4
9	1,114	15.5	9	2,214	30.8	9	3,314	46.3
10	1,272	17.8	10	2,372	33.1	10	3,472	48.5
5D1	3,628	50.6	5E1	4,728	66.0	5F1	5,828	81.4
2	3,679	51.4	2	4,779	66.7	2	5,879	82.1
3	3,788	52.9	3	4,888	68.3	3	5,988	83.6
4	3,921	54.8	4	5,021	70.1	4	6,121	85.5
5	4,079	57.0	5	5,179	72.3	5	6,279	87.7
6	4,178	58.4	6	5,278	73.7	6	6,378	89.0
7	4,229	59.1	7	5,329	74.5	7	6,429	89.7
8	4,338	60.5	8	5,438	76.0	8	6,538	91.2
9	4,471	62.4	9	5,571	77.8	9	6,671	93.2
10	4,629	64.6	10	5,729	80.0	10	6,829	95.4

DROP TESTS.

Four drop tests were made of each rail, two with the head in tension and two with the base in tension. The tup was 2,000 lbs., the height of drop was 20 ft., the centers of the supports were 3 ft. apart, and the anvil was the standard spring supported anvil of 20,000 lbs. The striking surface of the tup and the bearing surfaces of the supports had radii of 5 inches. The deflection was measured after the first blow and was taken as the distance between a 3-ft. straight edge and the part of the rail where struck by the tup. Gage marks one inch apart were put lengthwise on the side in tension about the middle of the test piece for a distance of 6 in., and the length of the space which stretched most at failure was taken as the measure of the ductility of the rail. The results of the drop tests are shown in tables 39 to 43 inclusive. Considerable difficulty was had keeping the surfaces of the bearings and striking die in satisfactory condition, and although frequent changes were made during the testing of this lot of rail specimens, some of the cases of low ductility were probably due to the "curling up" of the base due to a slight concavity of the supports or die, causing a flange break before the longitudinal ductility of the part in tension was exhausted. Probably the slow bending tests in the test machine described later were more satisfactory in this respect.

A few small internal flaws were found in this series of rails. Sample 4 A 3 at 6.0 per cent. from the top of the ingot showed a small flaw in the interior of the head. Sample 5 A 3 also at 6.0 per cent. from the top showed a one-half inch lamination in the lower part of the web near the side and sample 5 A 9 at 15.5 per cent. showed a small lamination in the head near the web.

TABLE 39—DROP TESTS, RAIL-BAR 1—.15% SILICON.

No.	Per Cent from Top of Ingot	Part in Tension	Deflection, 1st Blow	No. of Blows	Elongation, Per Cent
1A3	6.1	Head	1.39	3	20
1A8	13.6	Head	....	1	5
1B3	21.1	Head	....	1	10
1B8	28.6	Head	1.35	2	10
1C3	36.1	Head	1.34	3	18
1C8	43.6	Head	1.28	2	13
1D3	52.1	Head	1.39	4	14
1D8	59.6	Head	1.37	3	18
1E3	67.1	Head	1.41	2	10
1E8	74.6	Head	1.38	3	22
1F3	82.1	Head	1.36	2	10
1F8	89.7	Head	1.31	3	20
Average			1.36	2.4	14.3
1A4	7.9	Base	....	1	5
1A9	15.4	Base	1.32	3	12
1B4	22.9	Base	1.29	3	12
1B9	30.4	Base	....	1	0
1C4	37.9	Base	1.27	4	18
1C9	45.5	Base	....	1	1
1D4	53.9	Base	....	1	5
1D9	61.4	Base	1.32	4	22
1E4	68.9	Base	1.33	3	16
1E9	76.5	Base	1.33	4	20
1F4	83.9	Base	1.36	2	7
1F9	91.5	Base	1.32	3	14
Average			1.32	2.5	11.0
Gen. Aver.			1.34	2.5	12.6

TABLE 40—DROP TESTS, RAIL-BAR 2—.25% SILICON.

No.	Per Cent from Top of Ingot	Part in Tension	Deflection, 1st Blow	No. of Blows	Elongation, Per Cent
2A3	6.0	Head	....	2	11
2A8	13.5	Head	1.29	2	9
2B3	21.0	Head	1.32	3	14
2B8	28.6	Head	....	1	6
2C3	36.1	Head	1.34	2	10
2C8	43.6	Head	1.35	3	13
2D3	53.5	Head	1.29	3	20
2D8	61.1	Head	1.37	3	17
2E3	68.6	Head	1.38	2	14
2E8	76.2	Head	1.35	3	14
2F3	83.7	Head	1.39	2	9
2F8	91.1	Head	1.41	2	9
Average			1.35	2.3	12.2
2A4	7.8	Base	1.27	3	14
2A9	15.3	Base	1.24	4	23
2B4	22.8	Base	1.30	2	6
2B9	30.4	Base	1.30	3	17
2C4	37.9	Base	1.27	4	18
2C9	45.5	Base	1.32	4	20
2D4	55.3	Base	....	1	2
2D9	62.9	Base	1.32	3	8
2E4	70.4	Base	1.33	3	12
2E9	78.0	Base	1.37	3	18
2F4	85.5	Base	1.31	3	16
2F9	93.0	Base	1.31	3	12
Average			1.30	3.0	13.8
Gen. Aver.			1.33	2.7	13.0

TABLE 41—DROP TESTS, RAIL-BAR 3—.33% SILICON.

No.	Per Cent from Top of Ingot	Part in Tension	Deflection, 1st Blow	No. of Blows	Elongation, Per Cent
3A3	5.8	Head	1.41	2	8
3A8	13.3	Head	1.31	3	18
3B3	20.8	Head	1.32	2	12
3B8	28.3	Head	1.30	4	16
3C3	35.8	Head	1.32	2	11
3C8	43.3	Head	1.39	2	8
3D3	52.7	Head	1.41	2	8
3D8	60.3	Head	1.29	2	13
3E3	67.8	Head	1.34	2	10
3E8	75.4	Head	1.33	3	12
3F3	82.8	Head	1.38	3	15
3F8	90.3	Head	1.36	3	19
Average			1.35	2.5	12.5
3A4	7.6	Base	1.32	3	13
3A9	15.1	Base	....	1	4
3B4	22.6	Base	1.32	2	12
3B9	30.1	Base	....	1	3
3C4	37.6	Base	1.33	4	17
3C9	45.1	Base	....	1	4
3D4	54.6	Base	1.30	3	16
3D9	62.1	Base	1.31	3	12
3E4	69.6	Base	1.32	3	17
3E9	77.1	Base	1.35	3	22
3F4	84.6	Base	1.32	3	14
3F9	92.1	Base	1.39	4	18
Average			1.33	2.5	12.7
Gen. Aver.			1.34	2.5	12.6

TABLE 42—DROP TESTS, RAIL-BAR 4—.45% SILICON.

No.	Per Cent from Top of Ingot	Part in Tension	Deflection, 1st Blow	No. of Blows	Elongation, Per Cent
4A3	6.0	Head	....	1	5
4A8	13.6	Head	....	1	8
4B3	21.1	Head	1.29	2	12
4B8	28.7	Head	1.28	2	8
4C3	36.2	Head	1.30	3	16
4C8	43.8	Head	1.32	2	12
4D3	53.1	Head	1.41	2	14
4D8	60.7	Head	1.30	3	15
4E3	68.2	Head	1.30	2	12
4E8	75.8	Head	1.39	2	8
4F3	83.3	Head	1.38	3	16
4F8	90.9	Head	....	1	6
Average			1.33	2.0	11.0
4A4	7.8	Base	1.25	3	17
4A9	15.4	Base	1.29	3	14
4B4	22.9	Base	....	1	9
4B9	30.5	Base	....	1	3
4C4	38.0	Base	1.30	3	17
4C9	45.6	Base	1.29	3	14
4D4	55.0	Base	1.22	4	22
4D9	62.5	Base	1.30	3	10
4E4	70.0	Base	1.34	4	17
4E9	77.6	Base	....	1	5
4F4	85.2	Base	....	1	4
4F9	92.7	Base	1.32	4	20
Average			1.29	2.6	12.7
Gen. Aver.			1.31	2.3	11.8

TABLE 43—DROP TESTS, RAIL-BAR 5—.54% SILICON.

No.	Per Cent from Top of Ingot	Part in Tension	Deflection, 1st Blow	No. of Blows	Elongation, Per Cent
5A3	6.0	Head	....	1	4
5A8	13.8	Head	....	1	6
5B3	21.4	Head	1.32	2	8
5B8	29.0	Head	1.27	2	12
5C3	36.8	Head	1.28	3	16
5C8	44.4	Head	1.26	2	12
5D3	52.9	Head	1.30	2	16
5D8	60.5	Head	1.28	3	14
5E3	68.3	Head	1.28	3	18
5E8	76.0	Head	1.32	2	13
5F3	83.6	Head	1.38	2	8
5F8	91.2	Head	1.37	3	12
Average			1.31	2.2	11.6
5A4	7.9	Base	1.27	4	18
5A9	15.5	Base	1.31	2	8
5B4	23.2	Base	1.25	3	14
5B9	30.8	Base	1.31	3	16
5C4	38.6	Base	1.29	3	18
5C9	46.3	Base	....	1	4
5D4	54.8	Base	1.25	4	16
5D9	62.4	Base	1.28	3	9
5E4	70.1	Base	1.32	4	20
5E9	77.8	Base	1.37	3	14
5F4	85.5	Base	1.34	2	12
5F9	93.2	Base	1.31	3	12
Average			1.30	2.9	12.6
Gen. Aver.			1.30	2.5	12.1

Some of the samples tested showed deep longitudinal seams in the bottom of the base, although it is probable other samples also contained such seams but which were not opened up by the test. The seams which were found are shown in table 44.

TABLE 44—SEAMS FOUND IN DROP TEST.

Sample.	No. of blows.	Elong. per cent.	Seam.
2 E 4....	3	12	Long seam .07 inch deep.
2 F 8....	2	9	Long seam .12 inch deep.
2 F 9....	3	12	Long seam .08 inch deep.
3 D 3....	2	8	Long seam .05 inch deep.

It will be noted from this table that the presence of the seams in the base had only a small influence on the ductility in this series of drop tests.

DUCTILITY IN DROP TEST.

As already stated, the inch which stretched most at failure in the drop test was taken as the measure of the ductility of the piece of rail tested and the elongation results for the five rail-bars are plotted in fig. 10, the elongation being represented vertically and the distance from the top

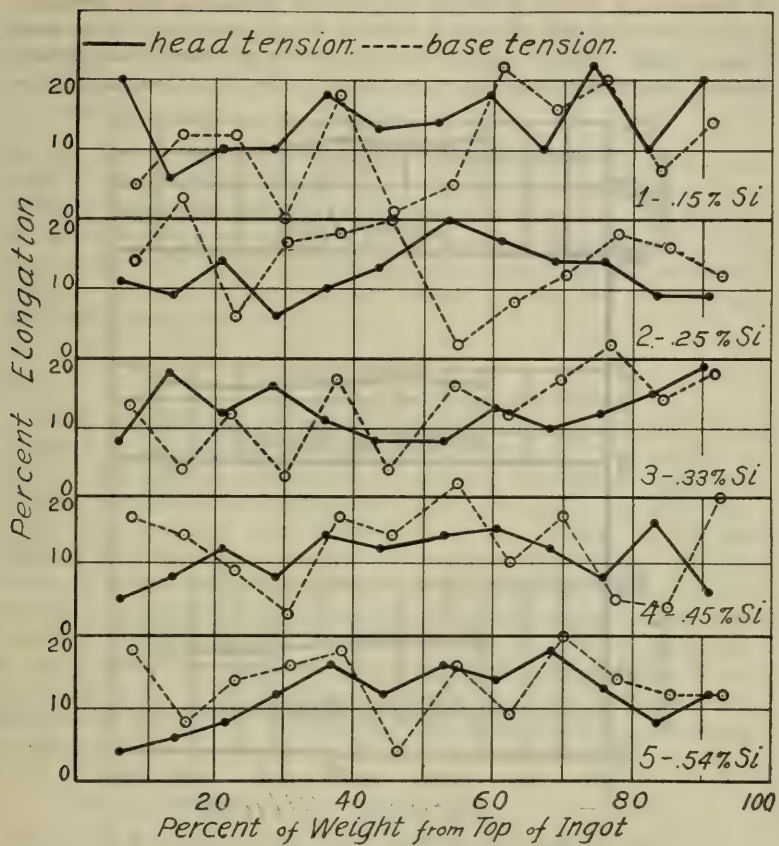


FIG. 10—ELONGATION IN DROP TEST OF THE FIVE RAIL-BARS AS RELATED TO DISTANCE FROM TOP OF INGOT.

of the ingot in per cent. of the total weight being represented horizontally. For each rail-bar one curve represents the results with the head in tension and another curve represents the results with the base in tension. The most prominent feature of these curves is perhaps the irregularity of the results, particularly with the base in tension and, as already explained, this may be at least in part due to the difficulty in keeping the bearing surfaces in satisfactory condition. There seem to be no prominent differences between the various bars with different silicon contents.

INFLUENCE OF SILICON IN DROP TEST.

In order to compare the results with the various silicon contents, table 45 is given showing the average results in the drop tests of each of the rail-bars showing the deflection after the first blow from 20 ft., the number

of blows that it took to break the rail, and the elongation after breaking with the head and with the base in tension, and the average of all the tests from each bar. The averages of the head tension and base tension results for each bar are plotted in Fig. 11 in relation to the silicon contained in the

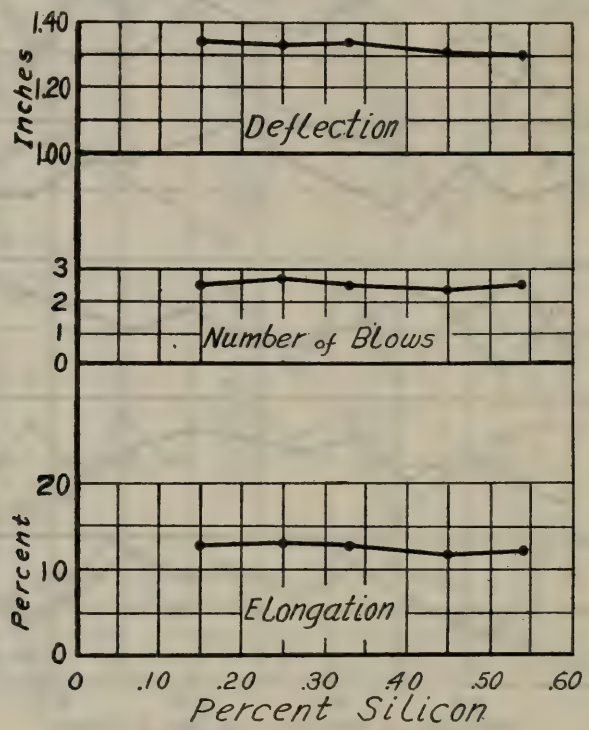


FIG. 11—RESULTS IN DROP TEST AS RELATED TO PER CENT. OF SILICON.

bar as shown by analysis of samples from each of the D rails. *According to these various results silicon between the limits of .15 and .54 per cent.*

TABLE 45—AVERAGE RESULTS IN DROP TEST.

Rail-bar number	1	2	3	4	5
Silicon, per cent.	.15	.25	.33	.45	.54
Deflection, first blow					
Head tension	1.36	1.35	1.35	1.33	1.31
Base tension	1.32	1.30	1.33	1.29	1.30
Average	1.34	1.33	1.34	1.31	1.30
Number of blows					
Head tension	2.4	2.3	2.5	2.0	2.2
Base tension	2.5	3.0	2.5	2.6	2.9
Average	2.5	2.7	2.5	2.3	2.5

Elongation					
Head tension	14.3	12.2	12.5	11.0	11.6
Base tension	11.0	13.8	12.7	12.7	12.6
Average	12.6	13.0	12.6	11.8	12.1

had but little influence on the results in the drop test, although it appears to have slightly increased the stiffness of the rail and to have slightly decreased the ductility with the larger amounts. The greatest average deflection was 1.34 in., with .15 per cent. silicon, and the least was 1.30 in., with .54 per cent. silicon. The greatest average elongation was 13.0 per cent., with .25 per cent. silicon, and the least was 11.8 per cent., with .45 per cent. silicon.

BENDING TESTS.

From each rail, two pieces were used for longitudinal bending in the test machine, one with the head in tension and the other with the base in tension. The rail was supported on flat supports, 3 ft. between edges, and the load was applied centrally between supports through a die with a 5-in. radius. The load was noted while the load was on when the rail had deflected .4 in., measured by means of a deflection gage placed under the middle of the rail and on the bed of the test machine. This was taken as a measure of the stiffness of the rail. The final breaking load also was measured. Gage marks one inch apart were put longitudinally on the side in tension, about the middle of the test piece, for a distance of 6 in. and the length of the space which stretched most at failure was determined and taken as a measure of the ductility. The results of the tests are shown in tables 46 to 50, inclusive:

TABLE 46—BENDING TESTS, RAIL-BAR 1—.15 PER CENT. SILICON.

No.	Per Cent. from Top of Ingot	Part in Tension	Load at. 4-in. Deflection	Breaking Load	Elongation, Per Cent.
1A5	10.0	Head	Broke	160,460	2
1B5	25.1	Head	186,530	257,290	6
1C5	40.1	Head	190,150	270,320	9
1D5	56.0	Head	180,940	260,570	10
1E5	71.1	Head	180,970	258,310	10
1F5	86.1	Head	179,210	255,320	11
Average			183,560	243,712	8.0
1A10	17 6	Base	184,200	286,980	15
1B10	32.6	Base	185,110	284,930	20
1C10	47.6	Base	186,750	261,230	4
1D10	63.6	Base	183,460	286,250	18
1E10	78.7	Base	180,360	277,560	14
1F10	93.6	Base	180,650	284,920	20
Average			183,422	280,312	15.2
Gen. Aver.			183,485	262,012	11.6

TABLE 47—BENDING TESTS, RAIL-BAR 2—.25 PER CENT. SILICON.

No.	Per Cent. from Top of Ingot	Part in Tension	Load at. 4-in. Deflection	Breaking Load	Elongation, Per Cent.
2A5	10.0	Head	182,460	258,120	9
2B5	25.0	Head	189,070	270,890	10
2C5	40.1	Head	187,820	269,150	10
2D5	57.5	Head	184,470	265,350	9
2E5	72.5	Head	183,020	262,010	10
2F5	87.7	Head	186,620	266,590	11
Average			185,577	265,352	9.8
2A10	17.5	Base	186,750	289,790	12
2B10	32.5	Base	191,230	291,860	13
2C10	47.6	Base	188,080	292,020	20
2D10	65.1	Base	185,160	272,930	6
2E10	80.2	Base	185,240	283,780	10
2F10	95.3	Base	187,380	292,510	19
Average			187,307	287,148	13.3
Gen. Aver.			186,442	276,250	11.6

TABLE 48—BENDING TESTS, RAIL-BAR 3—.33 PER CENT. SILICON.

No.	Per Cent. from Top of Ingot	Part in Tension	Load at. 4-in. Deflection	Breaking Load	Elongation, Per Cent.
3A5	9.8	Head	187,830	272,530	10
3B5	24.8	Head	190,200	278,250	12
3C5	39.8	Head	191,240	278,210	10
3D5	56.8	Head	190,050	274,570	11
3E5	71.8	Head	185,470	265,380	11
3F5	86.8	Head	182,940	266,740	12
Average			187,955	272,613	11.0
3A10	17.3	Base	191,030	294,860	13
3B10	32.3	Base	191,740	295,280	17
3C10	47.3	Base	189,380	295,170	16
3D10	64.3	Base	189,330	295,790	14
3E10	79.3	Base	187,870	290,750	11
3F10	94.4	Base	187,720	288,790	14
Average			189,512	293,440	14.2
Gen. Aver.			188,733	283,027	12.6

TABLE 49—BENDING TESTS, RAIL-BAR 4—.45 PER CENT. SILICON.

No.	Per Cent. from Top of Ingot	Part in Tension	Load at. 4-in. Deflection	Breaking Load	Elongation, Per Cent.
4A5	10.0	Head	192,540	276,620	10
4B5	25.1	Head	193,400	268,200	6
4C5	40.2	Head	195,360	277,570	10
4D5	57.1	Head	192,780	276,690	11
4E5	72.2	Head	187,870	270,700	12
4F5	87.3	Head	187,040	272,840	12
Average			191,498	273,770	10.2
4A10	17.5	Base	197,750	301,400	12
4B10	32.6	Base	195,870	301,000	17
4C10	47.7	Base	194,440	300,050	16
4D10	64.6	Base	196,970	303,540	22
4E10	79.8	Base	.....	298,130	13
4F10	95.0	Base	194,880	295,790	10
Average			195,982	299,985	15.0
Gen. Aver.			193,536	286,878	12.6

TABLE 50—BENDING TESTS, RAIL-BAR 5—.54 PER CENT. SILICON.

No.	Per Cent. from Top of Ingot	Part in Tension	Load at. 4-in. Deflection	Breaking Load	Elongation, Per Cent.
5A5	10.1	Head	192,730	277,970	11
5B5	25.2	Head	196,930	266,840	7
5C5	40.8	Head	197,310	278,230	7
5D5	57.0	Head	196,270	282,140	[illegible]
5E5	72.3	Head	191,090	270,980	8
5F5	87.7	Head	189,170	278,450	11
Average			193,917	275,768	8.8
5A10	17.8	Base	199,280	294,860	7
5B10	33.1	Base	197,120	303,810	10
5C10	48.5	Base	198,210	301,980	10
4D10	64.6	Base	200,000	306,410	12
5E10	80.0	Base	197,110	298,940	15
5F10	95.4	Base	194,200	298,860	13
Average			197,773	300,810	11.2
Gen. Aver.			195,845	288,289	10.0

For more convenient comparison the results showing load required for a .4-in. deflection, the breaking load and the elongation are plotted in relation to the distance from the top of the ingot, in Fig. 12, for rail-bars 1, 2 and 3, and in Fig. 13 for rail-bars 4 and 5. It will be noted that each bar had almost the same stiffness throughout its length, but in general was slightly stiffest at about 40 per cent. by weight from the top of the ingot and a trifle more so with the head in tension than with the base in tension. The stiffness with base in tension was a little greater than with the head in tension. In each bar the breaking load was, in general, roughly uniform throughout the length of the bar and was greater with the base in tension than with the head in tension. Sample 1 A 5 from rail-bar 1, with .15 per cent. silicon, and which was 10 per cent. by weight from the top of the ingot, broke at a very low load and broke before it gave .4-in. deflection. The elongations varied considerably in some bars, but averaged considerably higher with the base in tension than with the head in tension along the whole bar. There seems not to have been any general relationship between ductility and distance from the top of the ingot.

The average results for each rail-bar are collected together in table 51:

TABLE 51—AVERAGE RESULTS OF BENDING TESTS.

Rail-bar.	Silicon.	Load at .4-in. Deflection, Lbs. Head Tension.	Base Tension.	Gen. Avge.
1	.15	183,560	183,422	183,485
2	.25	185,577	187,307	186,442
3	.33	187,955	189,512	188,733
4	.45	191,498	195,982	193,536
5	.54	193,917	197,773	195,845
		Breaking Load, Lbs.		
1	.15	243,712	280,312	262,012
2	.25	265,352	287,148	276,250
3	.33	272,613	293,440	283,027
4	.45	273,770	299,985	286,878
5	.54	275,768	300,810	288,289
		Elongation in 1 in., Per Cent.		
1	.15	8.0	15.2	11.6
2	.25	9.8	13.3	11.6
3	.33	11.0	14.2	12.6
4	.45	10.2	15.0	12.6
5	.54	8.8	11.2	10.0

The results in this table are plotted in Fig. 14 in relation to the per-cent. of silicon contained in the rails. The stiffness of the rail as measured by the load required to produce a deflection of .4 in. while the load was on and the breaking load increased as the silicon increased. The averages of the head tension and base tension results showed a stiffness ranging from 183,485 lbs. for the bar with .15 per cent. silicon, to 195,845

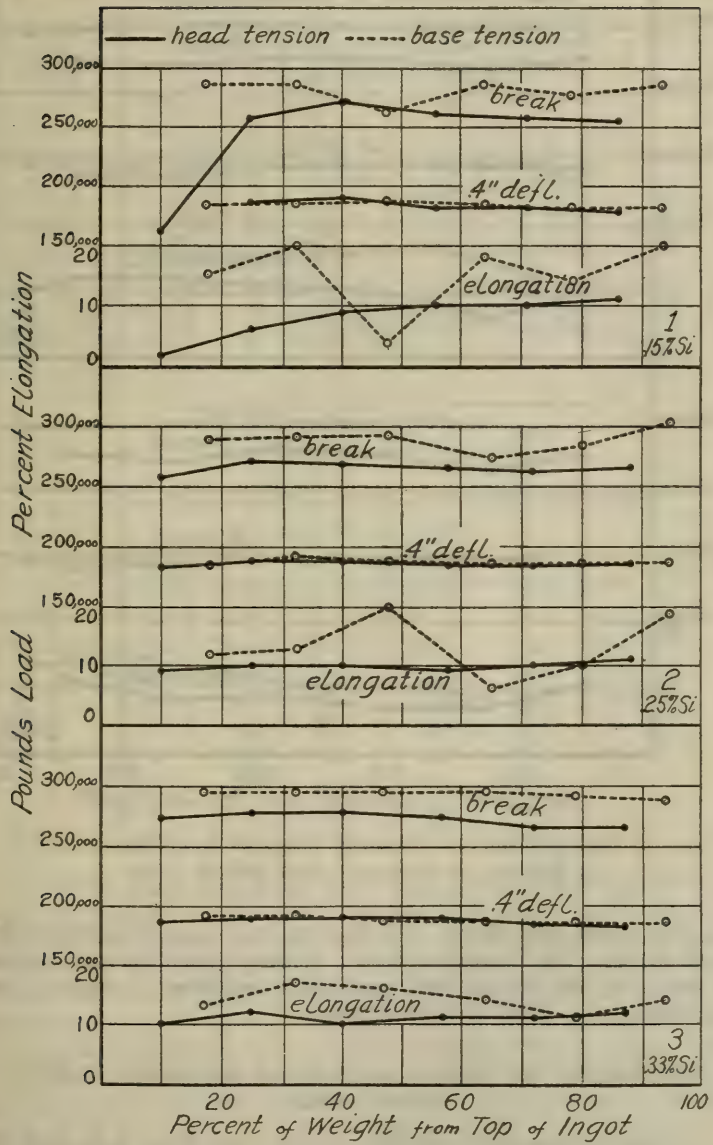


FIG. 12—RESULTS OF SLOW BENDING TESTS OF RAIL-BARS 1, 2 AND 3, AS RELATED TO DISTANCE FROM TOP OF INGOT.

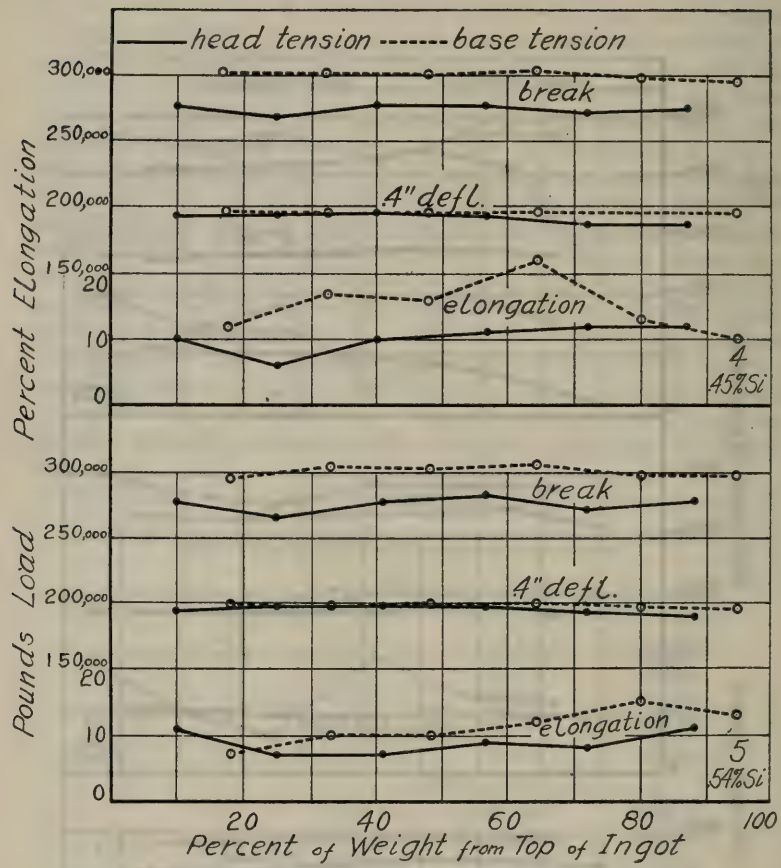


FIG. 13—RESULTS OF SLOW BENDING TESTS OF RAIL-BARS 4 AND 5, AS RELATED TO DISTANCE FROM TOP OF INGOT.

lbs., with .54 per cent. silicon. The breaking load ranged from 262,012 lbs. to 288,289 lbs. The elongation at first increased somewhat with increase of silicon beyond .15 per cent., reaching a maximum at about .4 per cent. silicon, after which it again decreased.

DUCTILITY IN DROP AND SLOW-BENDING TESTS COMPARED.

In order to compare the ductility of a rail as developed in the drop test with the ductility as developed in a slow-bending test, as in the test machine, the average results from each rail-bar by both methods are collected together in table 52.

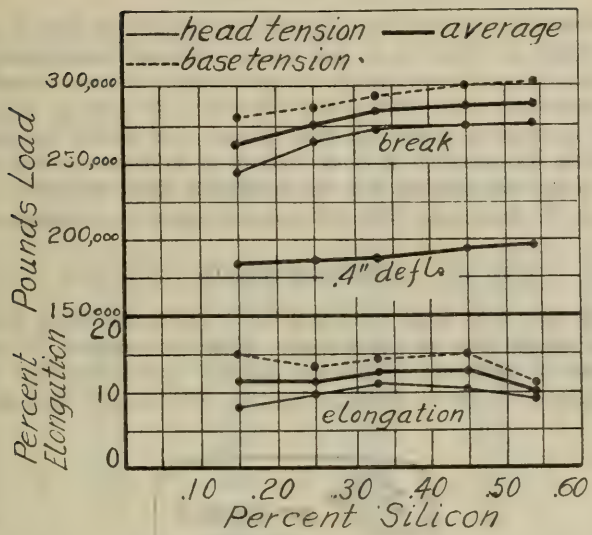


FIG. 14—RESULTS IN SLOW BENDING TESTS AS RELATED TO AMOUNT OF SILICON.

TABLE 52—ELONGATION IN DROP AND SLOW-BENDING TESTS.

	Head Tension.		Base Tension.		Gen. Avge.	
Rail-bar	Drop.	Bend.	Drop.	Bend.	Drop.	Bend.
1	14.3	8.0	11.0	15.2	12.6	11.6
2	12.2	9.8	13.8	13.3	13.0	11.6
3	12.5	11.0	12.7	14.2	12.6	12.6
4	11.0	10.2	12.7	15.0	11.8	12.6
5	11.6	8.8	12.6	11.2	12.1	10.0
Average	12.3	9.6	12.6	13.8	12.4	11.7

It will be noted that in the head tension tests the elongation was greater in the drop test than in the slow-bending tests with all the bars. In the base tension tests the elongation was sometimes greater and sometimes less and this was also the case with the general average results. In the drop test the full ductility was probably not obtained in all cases, due in such cases to first splitting the base on account of the condition of the supports and striking die, as already explained. The general average of all the results gave 12.4 per cent. elongation in the drop test and 11.7 per cent. in the slow-bending tests. As the height of drop was 20 ft., the speed of the tup at the time of striking would be about 36 ft. per second. At the instant of breaking, this speed would in some cases be almost exhausted, while in others it would be but little reduced by the work required to break the specimen. The speed of applying the load in

the test machine was not kept constant, but toward the end of each test may be taken as about .2 in. per minute, although considerably higher speeds were in most cases used at the beginning of the test. *These results do not determine with certainty the influence of the rate of speed on the ductility in bending a rail, but they indicate that within the limits that prevailed in this work, of 36 ft. per second in the drop test and .2 in. per minute in the slow-bending test, the ductility is about the same or a little greater in the drop test.* This difference of speed is as 129,600 to 1.

TENSILE TESTS.

Three tests were made from each half a rail length along each of the bars, one sample from the upper corner of the head marked "a," one from the interior of the head near the web marked "b," and the other from the flange marked "c," all as shown in Fig. 15. The samples from the corner

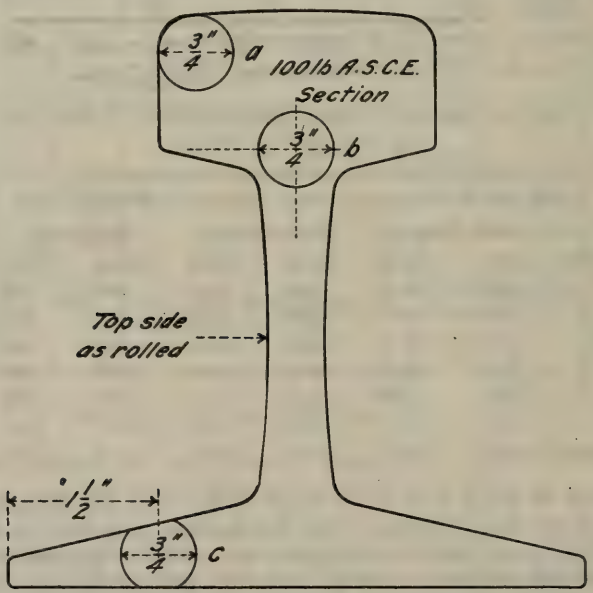


FIG. 15—LOCATIONS OF TENSILE SPECIMENS.

of the head and the flange were taken from the "top" side or side that was on top in rolling. The test pieces were ½ in. diameter for a gage length of 2 in. and the ends were ¾ in. threaded ends. The tests were made in a 300,000 lb. Riehle test machine, the test specimens being screwed into the ends of rounds which in turn were held by means of wedge grips. The yield point was determined by means of a Capp's multiplying dividers. The results of the tests are shown in tables 53 to 57 inclusive.

TABLE 53—TENSILE TESTS, RAIL-BAR I—.15% SILICON.

Test Number	Per Cent. from Top of Ingot	Yield Point, Pounds per Square Inch	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent. in 2 Inches	Reduction of Area, Per Cent.
1A1a	4.0	67,350	123,850	12.5	23.7
1A6a	11.4	58,800	126,150	11.0	15.6
1B1a	18.9	63,000	130,000	12.0	20.8
1B6a	26.4	66,350	126,100	13.5	20.9
1C1a	34.0	71,100	130,700	12.0	19.9
1C6a	41.5	63,150	129,150	14.0	20.6
1D1a	49.8	68,650	131,000	11.5	19.5
1D6a	57.4	58,700	124,900	13.0	19.8
1E1a	65.0	64,200	127,600	12.0	17.7
1E6a	72.5	67,690	125,800	13.0	20.7
1F1a	80.0	.....	128,300	11.0	20.9
1F6a	87.5	59,360	124,800	14.0	21.5
Average		64,395	127,362	12.4	20.1
1A1b	4.0	.....	135,100	3.0*	2.3
1A6b	11.4	.....	75,150	.5*	0.0
1B1b	18.9	71,000	109,200	1.0*	0.3
1B6b	26.4	70,900	134,350	3.5	2.8
1C1b	34.0	68,800	132,450	10.0	14.1
1C6b	41.5	61,250	125,500	13.0	17.5
1D1b	49.8	67,000	130,500	9.5	12.2
1D6b	57.4	55,850	123,600	11.5	13.7
1E1b	65.0	65,300	128,950	11.5	15.8
1E6b	72.5	63,500	121,200	14.0	19.9
1F1b	80.0	69,650	118,800	12.5	21.6
1F6b	87.5	63,250	116,500	14.5	21.2
Average		65,650	120,941	8.7	11.8
1A1c	4.0	64,300	129,450	7.5*	5.0
1A6c	11.4	60,300	125,600	14.0	22.3
1B1c	18.9	67,850	130,700	12.5	24.3
1B6c	26.4	68,130	130,500	13.5	22.1
1C1c	34.0	65,250	132,200	13.0	21.9
1C1c	41.5	.....	129,750	14.5	23.0
1D1c	49.8	72,250	131,950	13.0	22.3
1D6c	57.4	63,050	132,400	13.5	23.4
1E1c	65.0	66,220	131,800	12.5	22.1
1E6c	72.5	65,150	131,500	14.5	23.7
1F1c	80.0	67,540	129,300	13.5	22.4
1F6c	87.5	66,140	126,500	14.0	22.7
Average		66,016	130,137	13.0	21.2
Gen. Aver.		65,313	126,147	11.3	17.7

*Broke outside of gage marks.

TABLE 54—TENSILE TESTS, RAIL-BAR 2—.25% SILICON.

Test Number	Per Cent. from Top of Ingot	Yield Point, Pounds per Square Inch	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent. in 2 Inches	Reduction of Area, Per Cent.
2A1a	3.8	65,820	126,000	11.0	20.8
2A6a	11.3	.....	128,500	13.5	21.9
2B1a	18.8	68,150	131,650	11.0	19.1
2B6a	26.4	.....	127,800	8.0*	8.2
2C1a	33.9	63,750	131,300	12.0	19.1
2C6a	41.5	66,330	129,450	13.0	20.7
2D1a	51.4	67,720	130,400	13.0	20.6
2D6a	58.9	59,850	126,500	7.0*	5.4
2E1a	66.5	67,890	131,990	12.0	21.0
2E6a	74.0	61,550	128,300	13.5	20.9
2F1a	81.5	63,310	132,950	12.0	21.7
2F6a	89.0	64,500	126,800	13.0	22.3
Average		64,887	129,303	11.5	18.4
2A1b	3.8	62,550	124,300	6.0*	5.4
2A6b	11.3	63,400	.....	2.0*	2.2
2B1b	18.8	77,320	128,600	2.0*	1.6
2B6b	26.4	69,550	129,350	5.0*	3.6
2C1b	33.9	64,750	132,850	11.0	14.8
2C6b	41.5	61,950	120,600	13.0	18.4
2D1b	51.4	64,810	135,850	7.0*	5.5
2D6b	58.9	64,450	124,150	12.0	15.5
2E1b	65.5	68,970	127,800	11.0	18.2
2E6b	74.0	57,740	119,200	12.5	19.5
2F1b	81.5	66,010	121,400	12.0	20.0
2F6b	89.0	59,850	123,450	14.0	21.9
Average		65,154	126,140	8.9	12.2
2A1c	3.8	69,900	133,400	13.0	21.9
2A6c	11.3	63,160	132,400	14.0	22.1
2B1c	18.8	.....	129,800	12.5	22.3
2B6c	26.4	68,000	128,150	14.0	22.8
2C1c	33.9	69,300	135,100	14.0	24.0
2C6c	41.5	65,350	130,050	15.0	22.3
2D1c	51.4	70,200	132,500	12.5	21.9
2D6c	58.9	61,950	132,340	13.0	23.3
2E1c	66.5	62,450	133,800	12.5	21.9
2E6c	74.0	66,160	130,060	14.5	24.8
2F1c	81.5	62,750	132,200	13.0	22.6
2F6c	89.0	71,950	131,650	14.5	23.7
Average		66,470	131,788	13.5	22.8
Gen. Aver.		65,511	129,161	11.3	17.8

*Broke outside of gage marks.

TABLE 55—TENSILE TESTS, RAIL-BAR 3—.33% SILICON.

Test Number	Per Cent. from Top of Ingot	Yield Point, Pounds per Square Inch	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent. in 2 Inches	Reduction of Area, Per Cent.
3A1a	3.6	69,200	130,050	12.0	22.3
3A6a	11.1	64,850	128,650	14.0	21.6
3B1a	18.6	68,670	131,150	12.0	20.0
3B6a	26.1	61,650	124,900	6.0*	6.8
3C1a	33.7	62,200	130,100	13.5	21.2
3C6a	41.1	67,750	128,700	13.5	22.6
3D1a	50.6	71,500	133,600	9.0*	11.4
3D6a	58.1	63,500	128,750	14.5	22.5
3E1a	65.6	67,340	132,200	12.0	21.6
3E6a	73.1	61,150	127,600	14.0	21.6
3F1a	80.6	70,780	134,300	12.0	20.3
3F6a	88.1	63,150	128,750	14.5	22.6
Average		65,978	129,896	12.2	19.5
3A1b	3.6	68,750	126,250	12.0	18.2
3A6b	11.1	64,870	120,350	13.0	17.1
3B1b	18.6	77,650	109,100	1.5	1.1
3B6b	26.1	74,750	134,700	4.0*	2.7
3C1b	33.7	.....	129,450	5.0*	4.1
3C6b	41.1	62,700	131,750	7.0*	5.3
3D1b	50.6	65,100	127,050	10.5	16.6
3D6b	58.1	53,750	117,100	6.0*	5.8
3E1b	65.6	69,250	132,850	6.5*	10.8
3E6b	73.1	62,160	125,200	13.5	18.9
3F1b	80.6	66,000	124,950	12.0	20.8
3F6b	88.1	58,300	121,650	14.0	20.5
Average		65,752	125,033	8.7	11.8
3A1c	3.6	67,950	133,800	13.0	23.7
3A6c	11.1	71,300	135,350	14.5	23.2
3B1c	18.6	63,800	130,500	13.0	22.3
3B6c	26.1	65,260	128,700	14.0	23.8
3C1c	33.7	67,200	137,600	14.5	22.8
3C6c	41.1	65,400	128,700	14.0	23.3
3D1c	50.6	69,900	135,000	12.0	24.0
3D6c	58.1	76,400	138,600	14.0	23.4
3E1c	65.6	68,500	136,200	13.5	21.9
3E6c	73.1	72,180	133,800	14.5	24.5
3F1c	80.6	72,000	134,700	13.0	22.9
3F6c	88.1	63,000	131,900	11.0*	11.4
Average		68,574	133,737	13.4	22.1
Gen. Aver.		66,797	129,555	11.4	17.8

*Broke outside of gage marks.

TABLE 56—TENSILE TESTS, RAIL-BAR 4—.45% SILICON.

Test Number	Per Cent. from Top of Ingot	Yield Point, Pounds per Square Inch	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent. in 2 Inches	Reduction of Area, Per Cent.
4A1a	3.8	69,900	135,950	12.0	22.6
4A6a	11.4	72,600	132,400	13.5	20.3
4B1a	18.9	69,250	135,400	11.5	21.6
4B6a	26.5	67,100	132,700	14.0	21.9
4C1a	34.0	65,740	133,800	12.0	20.1
4C6a	41.6	64,820	134,700	12.0	19.3
4D1a	50.9	70,900	135,100	13.0	21.6
4D6a	58.5	63,400	126,550	13.0	18.4
4E1a	66.0	71,800	133,600	11.5	22.0
4E6a	73.6	64,570	130,900	13.5	21.4
4F1a	81.1	63,500	136,100	12.0	21.2
4F6a	88.7	66,300	134,200	13.5	20.9
Average		67,490	133,450	12.6	20.9
4A1b	3.8	64,450	130,000	12.0	17.0
4A6b	11.4	65,600	127,500	6.0*	5.8
4B1b	18.9	.....	86,550	1.0*	0.3
4B6b	26.5	79,300	140,500	4.5*	3.2
4C1b	34.0	64,600	130,350	8.0*	11.4
4C6b	41.6	65,150	128,900	11.5	16.2
4D1b	50.9	61,760	123,000	12.5	17.2
4D6b	58.5	64,380	129,800	7.0*	7.1
4E1b	66.0	72,700	133,050	10.0	16.9
4E6b	73.6	.....	123,800	13.0	19.2
4F1b	81.1	62,660	123,700	12.5	18.9
4F6b	88.7	59,800	125,400	13.0	20.5
Average		66,039	125,212	9.2	12.8
4A1c	3.8	72,500	135,800	12.5	21.9
4A6c	11.4	69,030	133,600	13.0	23.7
4B1c	18.9	71,200	135,400	14.0	17.8
4B6c	26.5	70,600	128,550	13.0	20.6
4C1c	34.0	71,120	133,900	13.5	22.8
4C6c	41.6	63,150	129,350	14.0	21.2
4D1c	50.9	68,050	137,000	13.0	23.0
4D6c	58.5	63,960	133,600	8.0*	7.4
4E1c	66.0	72,200	135,400	11.5	21.2
4E6c	73.6	73,250	134,400	14.5	23.0
4F1c	81.1	74,400	138,100	12.0	22.6
4F6c	88.7	62,750	128,950	13.5	22.0
Average		69,350	133,670	12.7	20.6
Gen. Aver.		67,720	130,777	11.5	18.1

*Broke outside of gage marks.

TABLE 57—TENSILE TESTS, RAIL-BAR 5—.54% SILICON.

Test Number	Per Cent. from Top of Ingot	Yield Point, Pounds per Square Inch	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent. in 2 Inches	Reduction of Area, Per Cent.
5A1a	3.8	68,500	133,050	11 5	20.5
5A6a	11.5	67,320	135,400	13.5	21.3
5B1a	19.2	74,300	135,000	13.5	22.3
5B6a	26.8	64,510	132,400	13.0	21 2
5C1a	34.5	71,670	134,600	13.0	21 9
5C6a	42.2	70,450	135,800	13.5	21.6
5D1a	50.6	77,150	141,250	12.0	21.9
5D6a	58.4	69,800	130,350	13.0	20.2
5E1a	66.0	73,350	137,950	12.0	20.5
5E6a	73.7	65,400	132,100	13.5	21.6
5F1a	81.4	63,720	135,800	12.5	19.8
5F6a	89.0	67,000	129,900	13.0	19.8
Average		69,430	134,466	12.8	21.0
5A1b	3.8	68,070	131,700	7.5*	7.1
5A6b	11.5	68,020	128,990	11.0	16.0
5B1b	19.2	.....	89,300	0.0	0.0
5B6b	26.8	67,200	138,150	4.5*	3.8
5C1b	34.5	66,280	137,000	10.0	16.2
5C6b	42.2	68,150	133,100	12.0	18.1
5D1b	50.6	68,900	124,400	5.5	5.4
5D6b	58.4	63,950	128,850	7.0	7.8
5E1b	66.0	68,000	131,250	11.0	16.6
5E6b	73.7	64,500	125,350	13.0	21.6
5F1b	81.4	68,100	.....	....	...
5F6b	89.0	62,000	125,400	13.5	19.4
Average		66,651	126,680	8.6	12.0
5A1c	3.8	75,000	137,850	14.0	23.1
5A6c	11.5	61,000	134,700	14.0	20.2
5B1c	19.2	78,210	138,450	12.0	21.7
5B6c	26.8	66,750	136,350	13.5	20.8
5C1c	34.5	72,400	137,000	12.0	22.6
5C6c	42.2	70,100	135,500	14.0	22.6
5D1c	50.6	71,200	141,400	13.5	23.3
5D6c	58.4	78,950	142,550	13.5	24.0
5E1c	66.0	69,700	135,950	11.5	20.5
5E6c	73.7	57,700	128,450	14.5	22.6
5F1c	81.4	69,480	134,990	11.5	22.8
5F6c	89.0	67,150	134,000	14.5	22.3
Average		69,803	136,432	13.2	22.2
Gen. Aver.		68,685	132,693	11.6	18.6

*Broke outside of gage marks.

The results showing the tensile strengths along each of the rail-bars are plotted in Fig. 16, the distance from the top of the ingot in per cent. of weight being represented horizontally and the tensile strength in pounds per square inch being represented vertically, and the results are plotted for the three positions of corner of head, interior of head and flange. It

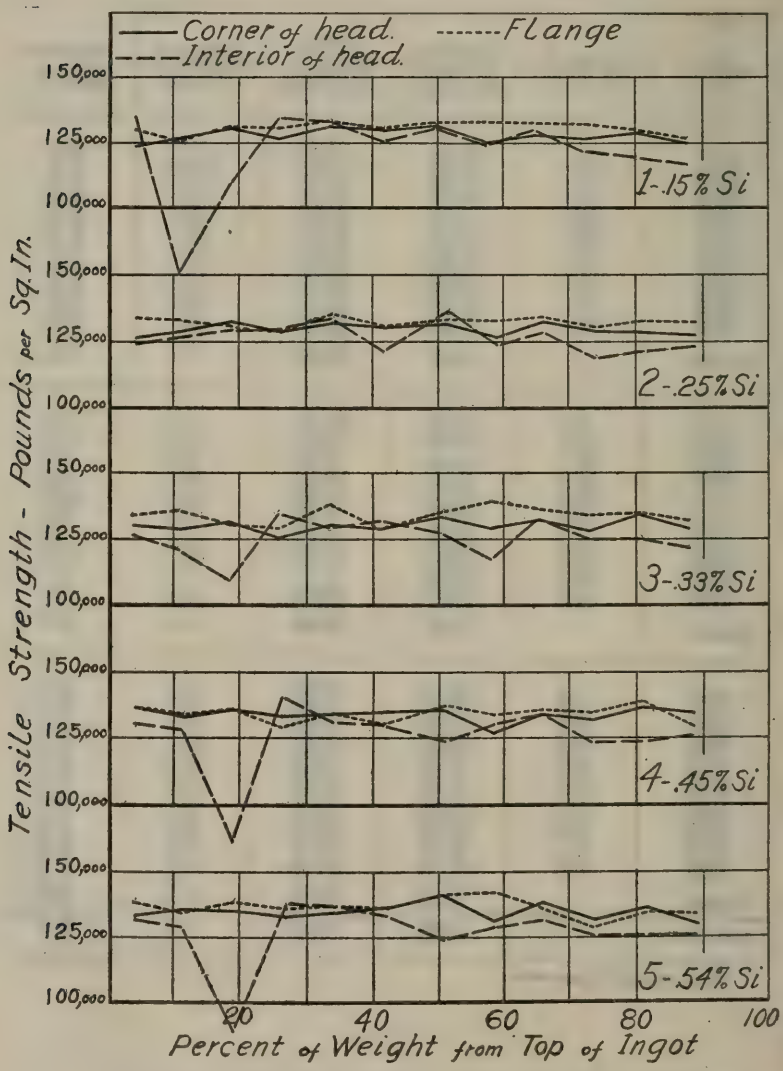


FIG. 16—TENSILE STRENGTH RESULTS OF THE FIVE INGOTS AS RELATED TO DISTANCE FROM TOP OF INGOT.

will be noted that the tensile strength of the corner of the head was in all the bars roughly uniform throughout the length of the bar. This was likewise so of the flange, but with a tensile strength averaging a little higher than the corner of the head. The samples from the interior of the head gave rather irregular results in all the bars. In the region between 10 and 20 per cent. from the top of the ingot, all the bars, except No. 2

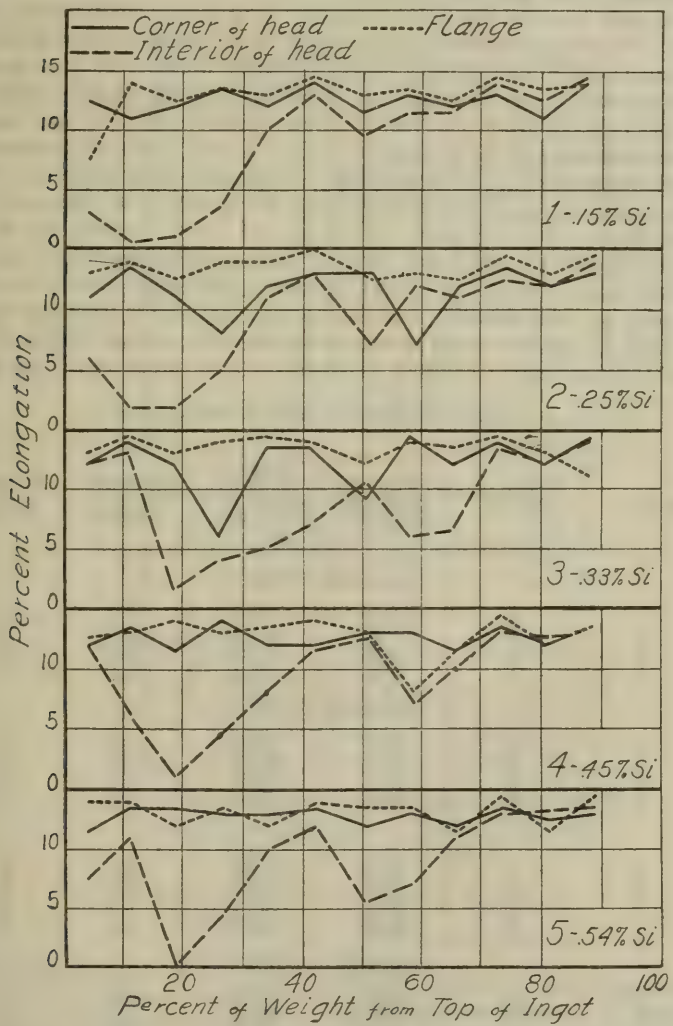


FIG. 17—ELONGATION IN TENSILE TESTS OF THE FIVE RAIL-BARS AS RELATED TO DISTANCE FROM TOP OF INGOT.

with .25 per cent. silicon, showed low tensile strength due evidently to low ductility and the test specimen breaking "short." In rail-bar 2 one of the two tensile strength results is unfortunately missing but we have the elongation results, showing low ductility in this bar also in this region, in the interior of the head.

The results showing the ductility of each bar are plotted in Fig. 17, the distance from the top of the ingot in per cent. of weight being plotted horizontally and the per cent. elongation in 2 inches being plotted vertically. The flange showed good ductility along the whole bar in all the bars and most of the samples from the corner of the head also showed good ductility along the whole bar in all the bars, but in bar 2 with .25 per cent. silicon and in bar 3 with .33 per cent. silicon, there was considerable irregularity in the elongation, which, however, seems not to have any special relationship to ingot position. The ductility of the interior of the head, however, varied considerably along the length of the bar in all the bars. Close to the top there was in general a fair ductility but in the region between 10 and 25 per cent. of the ingot from top of the bar the ductility was low in all the bars, the elongation dropping off to only a few per cent. or even nothing. At about 40 per cent. down from the top of the ingot, the interior metal reached a ductility almost equal to that of the rest of the sections. At about 50 or 60 per cent. down there was again

TABLE 58—AVERAGE TENSILE RESULTS.

Rail-bar	Silicon, Per Cent.	Yield Point, Pounds per Square Inch	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent. in 2 Inches	Reduction of Area, Per Cent.
		CORNER OF HEAD			
1	.15	64,395	127,362	12.4	20.1
2	.25	64,887	129,303	11.5	18.4
3	.33	65,978	129,896	12.2	19.5
4	.45	67,490	133,450	12.6	20.9
5	.54	69,430	134,466	12.8	21.0
		INTERIOR OF HEAD			
1	.15	65,650	120,941	8.7	11.8
2	.25	65,154	126,140	8.9	12.2
3	.33	65,752	125,033	8.7	11.8
4	.45	66,039	125,212	9.2	12.8
5	.54	66,651	126,680	8.6	12.0
		FLANGE			
1	.15	66,016	130,137	13.0	21.2
2	.25	66,470	131,788	13.5	22.8
3	.33	68,574	133,737	13.4	22.1
4	.45	69,350	133,670	12.7	20.6
5	.54	69,803	136,432	13.2	22.2
		GENERAL AVERAGE			
1	.15	65,313	126,147	11.3	17.7
2	.25	65,511	129,161	11.3	17.8
3	.33	66,797	129,555	11.4	17.8
4	.45	67,720	130,777	11.5	18.1
5	.54	68,685	132,693	11.6	18.6

some decline in the ductility which seems to have been more prominent with increase of silicon. At the lower end of the bar the ductility was about the same as in the rest of the section.

The average tensile results of the several bars are collected together in table 58.

For more convenient comparison these results are plotted in Fig. 18 in relation to the silicon content of the rails, except that in the case of the

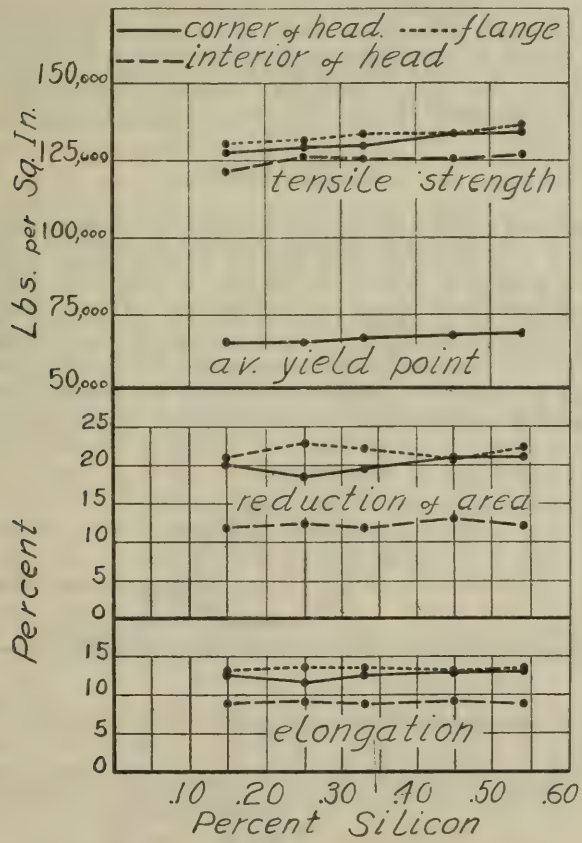


FIG. 18—RESULTS IN TENSILE TESTS AS RELATED TO PER CENT. OF SILICON.

yield point only the general average results are plotted, as the various section locations gave much the same results in the same rail-bar. It will be noted that the yield point increased slightly with increase of silicon from 65,313 lbs. per sq. in. with .15 per cent. silicon to 68,685 lbs. with .54 per cent. silicon, or an increase of 5.2 per cent. The carbon in these rails

averaged .70 per cent. The average tensile strength also increased from 126,147 lbs. per sq. in. to 132,693 lbs. for the above increase of silicon, or an increase of strength of 5.2 per cent. The average ductility as measured by the elongation in 2 inches and the reduction of area also showed slight increases. The average elongation increased from 11.3 per cent. to 11.6 per cent., an increase of 2.6 per cent., and the average reduction of area increased from 17.7 per cent. to 18.6, or an increase of 5.1 per cent. *According to this work, therefore, the average effect of each .01 per cent. increase of silicon between the limits of .15 and .54 per cent. with .70 per cent. carbon in open-hearth steel, was to increase the yield point by 86.5 lbs. per sq. in. and to increase the tensile strength by 167.8 lbs. per sq. in. The ductility remained about the same or increased slightly.*

FLANGE TESTS.

Flange tests or transverse tests of the base were made of pieces of rail a little over 2 ft. long from each half rail length along each of the rail bars. The method of making the test was to support the piece of rail on two supports placed opposite each other near the edges of the flanges under the middle of its length. The supports were 6 inches long and placed one-half inch in from the sides of the flanges and the load was applied in the test machine to the head of the rail at the middle. The general arrangement is shown in Fig. 19 and the details of the blocks and die

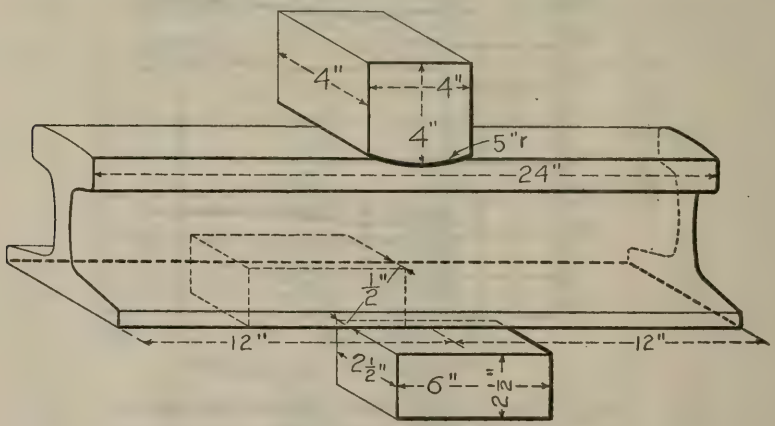


FIG. 19—METHOD OF MAKING FLANGE TEST.

were about as shown in Report No. 26 on Transverse Ductility of Base of Rails, A. R. E. A. Bulletin 147, July, 1912, page 303. The load was measured that it took to break the rail. The transverse elongation was measured by putting a prick-punch mark on the center line of the base

and then marking two one-inch spaces on each side of this crosswise on the bottom of the base and at the middle of the length of the piece tested. The greatest extension in any one of the four spaces after breaking was taken as the measure of transverse ductility. The sag of the unbroken flange was measured and was taken as the distance from a straight edge laid on the bottom of the base near the edge of the unbroken flange to the flange where bent most from the straight surface of the base. The flanges were not generally broken entirely off in the test machine by the breaking load, but they were later broken with a sledge and the fractures examined for seams. A few samples of the various types of fracture are shown in Fig. 20, from which it will be noted that in some cases a short curved piece was broken out at the flange while in other cases a long piece was broken out, with a long straight break at or near the middle of the base. This straight part in some cases followed along a seam in the base while in other cases there was no visible structural imperfection. A side view of these rails, showing the unbroken flanges, is given in Fig. 21.

Several of the samples showed deep seams in the base when the flanges were broken, as follows: No. 2 E 2, .08 in. deep; No. 2 F 7, .10 in. deep; and No. 4 E 7, .08 in. deep. A sample of one of these seams is shown in Fig. 22, which shows the fractured flange of No. 2 F 7.

The results of the flange tests are given in tables 59 to 63 inclusive. The results showing the breaking load, the transverse elongation and the sag of the flange, are plotted in Fig. 23 in relation to the distance from the top of the ingot. It will be noticed that there is considerable irregularity in the various results along the bars, but the low results in breaking load and transverse ductility seem to predominate in the lower part of the bar. It will also be noticed that the load, elongation and sag increase or decrease together in a general way.

TABLE 59—FLANGE TESTS, RAIL-BAR I—.15% SILICON.

No.	Per Cent. from Top of Ingot	Load, Pounds	Transverse Elongation, Per Cent	Sag, Inches	Break at Flange, Inches
1A2	4.6	137,210	1	.04	13.2
1A7	12.1	186,880	2	.18	10.5
1B2	19.6	161,420	1	.07	19.7
1B7	27.1	182,720	2	.13	15.1
1C2	34.6	159,340	1	.06	11.9
1C7	42.2	179,090	1	...	....
1D2	50.6	167,460	1	.08	14.2
1D7	58.1	195,890	2	.15	18.8
1E2	65.7	168,770	1	.09	22.5
1E7	73.2	129,730	1	.03	20.4
1F2	80.7	142,700	0	.05	17.5
1F7	88.2	153,470	1	.06	17.0
Average		163,723	1.2	.085	16.4

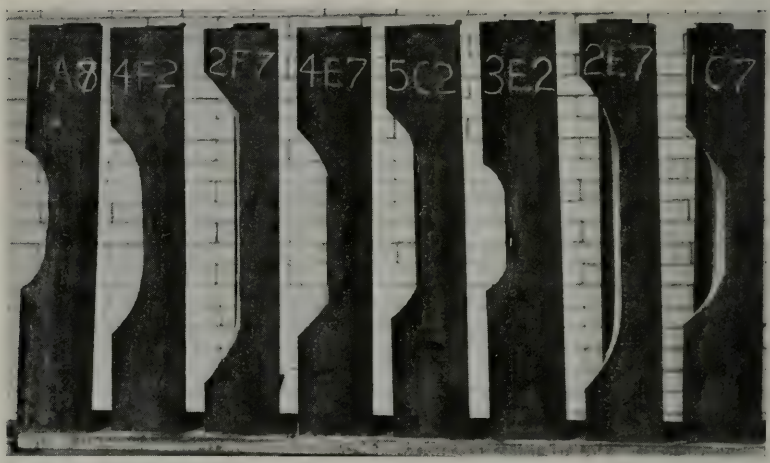


FIG. 20—SAMPLES OF FRACTURES IN FLANGE TESTS, BOTTOM VIEW.

FIG. 21—SAMPLES SHOWING SAG OF UNBROKEN FLANGES IN FLANGE TESTS, SIDE VIEW.

FIG. 22—VIEW OF LONGITUDINAL FRACTURE OF BROKEN FLANGE, SHOWING LONGITUDINAL SEAM IN THE BOTTOM OF THE BASE.

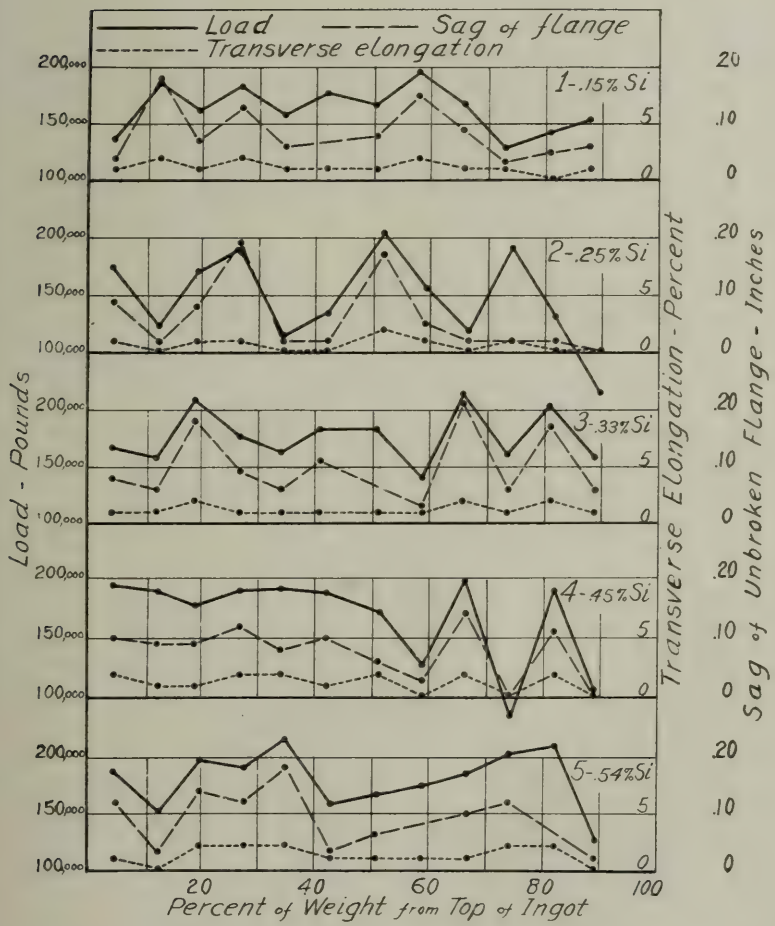


FIG 23—RESULTS OF FLANGE TESTS OF THE FIVE RAIL-BARS AS RELATED TO DISTANCE FROM TOP OF INGOT.

TABLE 60—FLANGE TESTS, RAIL-BAR 2—.25% SILICON.

No.	Per Cent. from Top of Ingot	Load, Pounds	Transverse Elongation, Per Cent.	Sag, Inches	Break at Flange, Inches
2A2	4.5	173,890	1	.09	12.0
2A7	12.0	122,460	0	.02	15.5
2B2	19.5	170,210	1	.08	16.0
2B7	27.1	189,920	1	.19	22.0
2C2	34.6	114,700	0	.02	19.0
2C7	42.2	133,930	0	.02	16.3
2D2	52.1	203,210	2	.17	14.6
2D7	59.6	156,250	1	.05	18.0
2E2	67.2	119,380	0	.02	15.5
2E7	74.7	190,270	1	...	23.0
2F2	82.2	130,610	0	.02	20.3
2F7	89.8	64,000	0	.00	straight
Average		147,403	.58	.062	16.9

TABLE 61—FLANGE TESTS, RAIL-BAR 3—.33% SILICON.

No.	Per Cent. from Top of Ingot	Load, Pounds	Transverse Elongation, Per Cent.	Sag, Inches	Break at Flange, Inches
3A2	4.3	167,490	1	.08	14.8
3A7	11.8	157,730	1	.06	18.5
3B2	19 3	209,010	2	.18	17.4
3B7	26.8	174,950	1	.09	18.4
3C2	34.3	162,640	1	.06	14.6
3C7	41.8	182,340	1	.11	18.2
3D2	51.3	181,820	1	...	22.0
3D7	58.8	139.580	1	.03	17.1
3E2	66.3	213,270	2	.21	11.3
3E7	73.8	160,110	1	.06	11.4
3F2	81.3	202,670	2	.17	12.7
3F7	88.9	159,050	1	.06	16.5
Average		175,888	1.3	.101	16.1

TABLE 62—FLANGE TESTS, RAIL-BAR 4—.45% SILICON.

No.	Per Cent. from Top of Ingot	Load, Pounds	Transverse Elongation, Per Cent.	Sag, Inches	Break at Flange, Inches
4A2	4.5	193,060	2	.10	13.5
4A7	12.1	188,580	1	.09	17.5
4B2	19.6	177,230	1	.09	9.3
4B7	27.2	188,810	2	.12	19.6
4C2	34.7	189,970	2	.08	11.3
4C7	42.2	187,650	1	.10	16.0
4D2	51.6	170,590	2	.06	16.8
4D7	59.2	129,160	0	.03	15.1
4E2	66.7	196,810	2	.14	15.0
4E7	74.3	83,380	0	.00	straight
4F2	81.8	189,100	2	.11	15.8
4F7	89.4	107,100	0	.00	17.5
Average		166,787	1.3	.077	15.2

TABLE 63—FLANGE TESTS, RAIL-BAR 5—.54% SILICON.

No.	Per Cent. from Top of Ingot	Load, Pounds	Transverse Elongation, Per Cent.	Sag, Inches	Break at Flange, Inches
5A2	4 5	188,090	1	.12	9.0
5A7	12.2	150,380	0	.03	20.5
5B2	19.9	198,860	2	.14	16 5
5B7	27 6	190,600	2	.12	19.5
5C2	35 2	215,230	2	.18	15.5
5C7	42.9	159,400	1	.03	14.8
5D2	51.4	167.750	1	.06	17.0
5D7	59 1	172,880	1	...	14.2
5E2	66 7	185,920	1	.10	15.8
5E7	74.5	201,770	2	.12	11.5
5F2	82.1	210,140	2	...	15 0
5F7	89.7	126,560	0	02	17 0
Average		180,632	1.3	.092	15.5

In order to show up the influence of silicon on the strength of the flange and its transverse ductility, the average results for each of the rail-bars are collected together in table 64.

TABLE 64—AVERAGE RESULTS OF FLANGE TESTS.

Rail-bar.	Silicon.	Load, lbs.	Transverse elongation, per cent.	Sag of unbroken flange.
1	.15	163,723	1.2	.085
2	.25	147,403	.58	.062
3	.33	175,888	1.3	.101
4	.45	166,787	1.3	.077
5	.54	180,632	1.3	.092

The results are also plotted in Fig. 24 in relation to the silicon content of the rails. Rail-bar 2 with .25 per cent. silicon gave low results but this evidently was due mostly or entirely to the presence of deep seams found in the E and F rails of this bar. *Allowing for this, it seems that the load required to break the flange increased somewhat as the amount of silicon increased between the limits of .15 and .54 per cent. The transverse ductility remained about the same. The amounts of silicon beyond .15 per cent., it will be remembered, were obtained by mold additions.*

SUMMARY.

1. An investigation was made concerning the influence of silicon in basic open-hearth steel ingots and rails between the limits of .15 per cent. and .54 per cent. silicon. Five ingots with varying silicons were used for splitting to note their internal condition as regards cavities and for chemical survey and five similar ingots were rolled into rails which were used for drop tests, slow bending tests, flange tests and tensile tests. The

lowest silicon was the natural silicon of the heat and the higher amounts were obtained by mold additions of finely crushed 50 per cent. ferro-silicon, sized so as to pass a No. 8 sieve but be retained on a No. 20 sieve. The work was done at Gary, Ind., at the works of the Illinois Steel Co., who kindly furnished all the material and facilities for making the investigation.

2. The average amounts of silicon in the several ingots were as follows: .17 per cent., .26 per cent., .34 per cent., .46 per cent., and .52 per cent. The average amounts of silicon in the several rail-bars were as

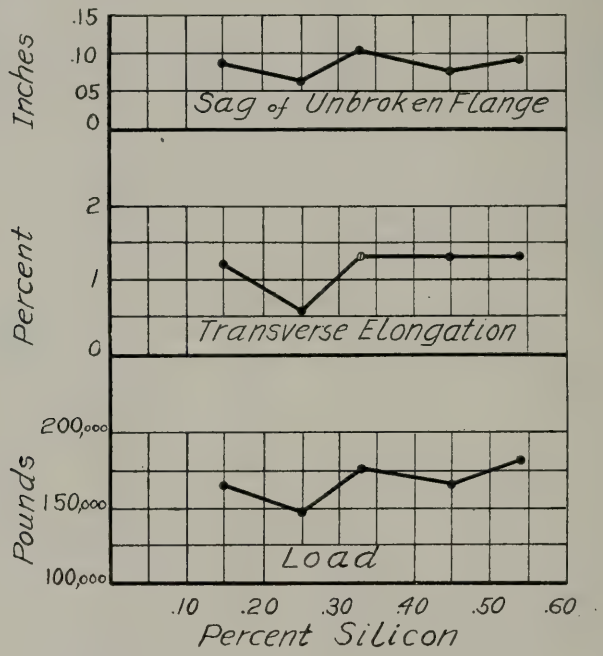


FIG. 24—RESULTS OF FLANGE TESTS AS RELATED TO PER CENT. OF SILICON.

follows: .15 per cent., .25 per cent., .33 per cent., .45 per cent. and .54 per cent.

3. The ingot with .17 per cent. silicon was spongy or honeycombed at the top end with cavities of various sizes, the sponginess at the axis extending about one-third way down the ingot. The other ingots with larger amounts of silicon were mostly free from the small holes, but contained large central cavities or pipes, with a few large holes under the roof of the ingot. The pipes extended downward from the top about one-third of the height and there was a slightly spongy condition at the axis extending intermittently to below the middle of the ingot.

4. A chemical survey was made of each of the five ingots by means of 15 samples from each of five vertical rows from one-half of each section face, making a total of 75 samples from each ingot, minus the samples which could not be taken on account of cavities. On each sample determinations were made of carbon, phosphorus, sulphur, manganese and silicon.

5. Silicon in amounts of .26 per cent. or over was attended with less segregation in the interior and upper part of the ingot than occurred in the open-hearth steel with .17 per cent. silicon. The thought is expressed that this may have been due in part to the large pipe not allowing the metalloids to concentrate into so small a volume.

6. Silicon between the limits of .15 and .54 per cent. had little influence on the results in the drop test, although it appears to have slightly increased the stiffness of the rail and to have slightly decreased the ductility with the larger amounts.

7. A few samples were found in the drop test with deep seams in the base.

8. Bending tests were made in the test machine. The stiffness of the rail, as measured by the load required to produce a 4-in. deflection while the load was on, and the breaking load, increased as the silicon increased. The average stiffness ranged from 183,485 lbs. with .15 per cent. silicon to 195,845 lbs. with .54 per cent. silicon. The breaking load increased from 262,012 lbs. to 288,289 lbs. The elongation at first increased somewhat with increase of silicon beyond .15 per cent., reaching a maximum at about .4 per cent. silicon, after which it again decreased.

9. A comparison of the ductility in the drop test and the slow bending test indicated that the ductility was influenced little, if any, by the rate of application of the load between the limits which prevailed in these tests of 36 feet per second in the drop test and .2 inch per minute in the slow bending test.

10. In the tensile test, the yield point and tensile strength increased somewhat with increase of silicon. The average effect of each .01 per cent. increase of silicon between the limits of .15 and .54 per cent. with .70 per cent. carbon in open-hearth steel, was to increase the yield point by 86.5 lbs. per sq. in. and to increase the tensile strength by 167.8 lbs. per sq. in. The ductility remained about the same or increased slightly.

11. Flange tests or transverse tests of the base were made by supporting pieces of rail about 2 feet long, on two supports placed opposite each other near the edges of the flanges under the middle of the length of the piece tested. The supports were 6 inches long and placed one-half inch in from the sides of the flanges and the load was applied in the test machine to the head of the rail at the middle.

12. The load required to break the flange increased somewhat as the amount of silicon increased between the limits of .15 and .54 per cent. The transverse ductility remained about the same.

13. To sum up, the ingot with .17 per cent. silicon was honeycombed in its upper third while those with .26 per cent. or more of silicon were

free from most of the honeycomb but contained larger pipes. There was also a less concentrated segregation of carbon, phosphorus and sulphur in these latter ingots. Silicon had but little influence on the results in the drop test. When tested in the test machine as a beam the stiffness and breaking load of the rails increased with increase of silicon while their ductility was not greatly influenced. In longitudinal tensile tests, the yield point and tensile strength increased somewhat with increase of silicon while the ductility remained about the same. In tests of the flange, the load required to break the flange increased somewhat as the silicon increased, while the transverse ductility of the base remained about the same. The silicon in this work above the amount in the heat of about .15 per cent. silicon was obtained by mold additions of finely crushed ferro-silicon.

Appendix M.

STREMMATOGRAPH TESTS OF TRACK UNDER SERVICE CONDITIONS.

By Dr. P. H. Dudley,

Consulting Engineer, New York Central Lines.

The locomotives in all three tests were the Atlantic type, Class I. Weight on forward truck, 37,000 lbs.; on drivers, 105,000 lbs.; on trailing wheel, 34,000 lbs.; on tender loaded, 114,000 lbs. The truck and tender wheels were each 36 in. in diameter, drivers, 79 in., trailer, 50 in.

Wheel spacing of engine truck	70 in.
Truck to front driver	59 in.
Spacing of drivers	84 in.
Driver to rear trailing wheel	114 in.
Trailer wheel to front tender truck wheel	110½ in.
Spacing of each tender wheel truck	5 ft. 3 in.
Wheel spacing between rear front truck wheel and front rear tender truck	6 ft. 6½ in.

The tabulations refer only to the locomotives in these three tests. In tests 362 and 342, there is a designation for extra wave preceding truck wheel. This is not usually found upon firm ground, but frequently occurs on embankments and made ground.

The unit fiber stresses of compression in front of the truck wheel in test 362 was 1,417 lbs., followed immediately by a unit fiber stress of tension of 12,754 lbs. for the front truck wheel. This is usually higher than the following wheel for two reasons; first, that the truck wheel is taking up some looseness of the track, in depressing the rail from the Trackman's Surface to its lower loaded position in what is called the "Equilibrium Depression" of the track; second, the short spacing between the front driver and rear truck wheel tilting up the truck.

It will be noticed that when the counterweight of the front driver was up over the Stremmatograph, the unit fiber stresses were no greater under it than under the front truck wheel. The counterweight in the main driver was descending, but did not reach the rail until about three feet beyond the Stremmatograph, the unit fiber stresses being 20,785 lbs.

The static load upon the trailing wheel, it will be seen, is less than upon the drivers, but owing to its longer wheel spacing, the maximum unit fiber stresses of tension, 24,328 lbs. are obtained under that wheel.

The unit fiber stress under the front tender wheels was 15,825 lbs., in part due to the roughness of the wheel, which was greater than normal, due to generated wheel effects. Such conditions are found fre-

quently to occur in actual tests made in the track, which would not be anticipated by calculations.

The positive bending and negative bending moments are tabulated in the last two columns. The maximum positive bending moments is 277,339 in.-lbs., which it will be noted is under the trailing wheel. The unit fiber stresses will be found by comparison to be greater in the 80-lb. than in the 100-lb. section, while the larger bending moments in inch-pounds will be found in 100-lb. rails.

The unit fiber stresses were larger as a rule under the lighter rails than in the 80 and 100-lb., but their small mechanical properties did not enable them to carry large bending moments. The positive and also the negative bending moments are all tabulated and reduced per pound of static load for one rail. This enables a comparison to be made between the stresses produced by the different types of locomotives. The 10-wheel and Pacific type of engines, by their more uniform loading of the track in the Equilibrium Depression, draw their trains with lower unit fiber stresses per ton on the drivers than the ordinary American eight-wheel engine, the tractive effort being distributed between six instead of four drivers. The consolidation type of engine for freight purposes, with its close wheel spacing, makes a favorable Equilibrium Depression, for both the rails and the roadbed, and reduces the unit fiber stresses per ton of static load to lower limits than would be possible for the eight-wheel American type of engine. The rolling wheel or driving wheel contacts load the rails for either the locomotive or cars, the spans of the bending rails being fixed by the wheel spacing.

The Stremmatograph tests show that the spans of the bending rails are controlled by the wheel spacing of the locomotive or cars, though the cross-ties furnish the support to the rails and lessen the deflections, yet the length of the bending span is determined by the wheel spacing practically in most cases so far observed. This can be confirmed by levels of standing locomotives upon the track.

Some of the important facts shown by the Stremmatograph tests are the transitory depression of the rails, cross-ties, ballast and roadbed, from the Trackman's Surface to the Equilibrium Depression under the superimposed moving locomotives and cars, and the dependent action of each wheel upon adjacent wheels, in their respective wheel bases upon and through the tracks.

The equalizing systems of the equipment are in action over the inequalities of the track, and their distribution of the loads is controlled as though from the center of gravity of each locomotive or car, therefore the stresses from a single wheel may not be comparable, but the total for a locomotive or car of the same class and doing the same work should compare with a high degree of precision.

Test 342 was the light engine backing up over the track to take its train. The total wheel effects for the light locomotive in the tabulations were 1,368,706 in.-lbs. This, compared with the wheel effects in inch-

pounds when the same engine ran over the same track drawing its train, expending nearly 1,000 H.P., was 1,864,363 in.-lbs. in one rail; an increase of 495,657 in.-lbs., due to the expended tractive effort to draw its train. Comparing the unit fiber stresses of the light engine in Test 342 with that of Test 344 on the 100-lb. rails, shows the strains were increased under all the wheels.

The effect is largest when the locomotive is rapidly accelerating its train, and when uniform speed is attained, the expended tractive effort per foot run will be less than when exerting greater power at slower speeds. The effect, however, on rails in the cold is sufficient to induce some fractures, and the expended tractive effort must be taken into account in considering the question of rail breakages. The drawbar pull for a heavy passenger train of 6 to 12 cars may be sufficient to affect the impact of a slightly eccentric wheel to break the rails in low temperatures.

P. H. DUDLEY'S STREMMATOGRAPH TESTS MAY 25, 1901.

No. 342. Track No. 3. Location between 48th and 49th Streets, G. C. Station, Rail 6 inches 100 lb. Moment of inertia 48.5 4th power inches. Crossties. Length, 8 feet. Width, 9 inches. Thickness, 6 inches. Wood, oak. Weight 160 lb. No. 16 per 30-foot rail. Average weight of superstructure per yard, 454 lb. Three-tie supported joints, 36-inch splice bars, Stone ballast. Locomotive No. 2988, Weight 290,000 lb. Speed 5 miles per hour. Temperature, 100° Fahr. Remark, engine backing up light.

The apparent mean unit fiber-stresses in the base of one rail were as follows in pounds:-

		Per wheel.	Per Wheel Base of			Per Pound of Wheel Base of	Wheel effects	
			Drivers and Trucks of Engine, Tender and Cars.	Engine and Tender	Locomotive and Cars.	Drivers and Trucks of Engine, Tender and Cars.	Positive bending moments under wheels inch pounds.	Negative bending moments between wheels, inch pounds.
	Extra wave preceding truck wheel.							
	Compression in front of truck wheel.....	708	--	--	--	--	--	11,753
Engine Truck	Tension under front truck wheel,.....4,960		--	--	--	--	82,336	--
Engine Truck	Compression between front and rear truck wheel, ...1,181		11,337	--	--	0.532	--	19,605
Engine Truck	Tension under rear truck wheel, ...4,252		--	--	--	--	70,583	--
	Compression between truck wheel and front driver,.....	472	--	--	--	--	--	7,835
T.W. Drivers	Tension under front driver, ...10,885		--	--	--	--	180,691	--
T.W. Drivers	Compression between drivers,.....	2,362	24,821	49,976	--	0.524	--	39,209
T.W. Drivers	Tension under main driver,.....10,157		--	--	--	--	168,606	--
	Compression between main driver and trailing wheel,.....	2,362	--	--	--	--	--	39,209
T.W.	Tension under trailing wheel,.....11,810		13,818	--	--	0.716	196,046	--
	Compression between trailing and front wheel of tender,.....	1,653	--	--	82,452	--	--	27,440
Tender F.T.	Tension under front tender wheels,.....	5,196	--	--	--	--	86,254	--
Tender F.T.	Compression between tender wheels, front truck, ...	472	14,998	--	--	0.550	--	7,835
Tender F.T.	Tension under rear tender wheel front truck,	7,795	--	--	--	--	129,397	--
Tender F.T.	Compression between front and rear tender truck, ...	1,417	--	32,476	--	--	--	23,522
Tender R.T.	Tension under front tender wheel rear truck	7,086	--	--	--	--	117,628	--
Tender R.T.	Compression between wheels of rear tender truck,.....	0	17,478	--	--	0.607	--	0
Tender R.T.	Tension under rear tender wheel, ...	9,212	--	--	--	--	152,912	--
	Compression between tender wheel and first car wheel,.....	472	--	--	--	--	--	7,835

LOCOMOTIVE

NOTE:--For test No. 342, rail strained in reverse order to that given in tabulations.

Reduction of Sum of Positive and Negative Bending Moments to one Pound of Static Load, for One Rail.

Engine.....	Sum of positive bending moments	698,260.00	inch-pounds	
--	-- of P.B.M. per pound of static load	7.93	--	--
--	-- of negative bending moments	131,331.00	--	--
--	-- of N.B.M. per pound of static load	1.42	--	--
Tender.....	-- of positive bending moments	486,198.00	--	--
--	-- of P.B.M. per pound of static load.....	8.53	--	--
--	-- of negative bending moments,.....	52,915.00	--	--
--	-- of N.B.M. per pound of static load	0.93	--	--
Locomotive.	-- of Positive bending moments 1,184,460.00		--	--
--	-- of P.B.M. per pound of static load	8.17	--	--
--	-- of negative bending moments	184,246.00	--	--
--	-- of N.B.M. per pound of static load.....	1.27	--	--
--	-- of wheel effects 1,368,706.00		--	--

P. H. DUDLEY'S STREMMATOGRAPH TESTS MAY 25, 1901

9.344. Track No.3. Location between 48th and 49th Streets G.C. Station. Rail 6 inches, 100-lb. Moment of inertia 48.5 4th power inches. Crossties. Length 8 feet. Width 9 inches. Thickness, 6 inches. Wood, oak. Weight 160 lb. No. 16 per 30-foot rail. Average weight of superstructure per yard, 454 lb. Three-tie supported joints, 36-inch splice bars, Stone ballast. Locomotive No. 2988. Weight 290,000 lb. Engine expending 1,000 H.P. drawing train No.3; Fast Mail, 9 cars; weight, 1,035,000 lb.; speed 16 miles per hour. Temperature, 100° Fahr.

The apparent mean unit fiber-stresses in the base of one rail, were as follows in pounds:-

		Per wheel.	Per wheel base of Drivers and trucks of engine, tender and cars.	Per wheel base of Engine and Tender	Per wheel base of Locomotive and Cars.	Per Pound of Wheel Base of Drivers and trucks of engine, tender and cars.	Wheel effects. Positive bending moments under wheels inch pounds.	Wheel effects. Negative bending moments between wheels inch-pounds.
Locomotive	Compression in front of truck wheel	1,181	--	--	--	--	--	19,605
Engine Truck	Tension under front truck wheel,	5,905	--	--	--	--	98,023	--
	Compression between front and rear truck wheel,	1,417	15,707	--	--	0.848	--	23,522
	Tension under rear truck wheel,	5,432	--	--	--	--	90,171	--
Engine Drivers	Compression between truck wheel and front driver	3,543	--	--	--	--	--	58,814
	Tension under front driver	22,911	--	--	--	--	380,323	--
	Compression between drivers	2,834	38,618	68,733	--	0.732	--	47,044
T.W.	Tension under main driver	9,448	--	--	--	--	156,837	--
	Compression between main driver and trailing wheel	3,307	--	--	--	--	--	54,296
	Tension under trailing wheel	11,101	14,408	--	--	0.821	184,277	--
	Compression between trailing and front wheel of tender	3,307	--	--	112,311	--	--	54,296
F.T.	Tension under front tender wheels	8,739	--	--	--	--	145,067	--
	Compression between tender wheels, front truck	2,362	19,958	--	--	0.725	--	39,209
	Tension under rear tender wheel front truck	6,141	--	--	--	--	101,941	--
	Compression between front and rear tender trucks	2,126	--	43,578	--	--	--	35,292
Tender R.T.	Tension under front tender wheel rear truck	10,157	--	--	--	--	168,606	--
	Compression between wheels of rear tender truck	1,653	23,620	--	---	0.859	--	27,440
	Tension under rear tender wheel	9,684	--	--	--	--	160,754	--
	Compression between tender wheel and first car wheel	2,126	--	--	--	--	--	35,292

Reduction of sum of Positive and Negative Bending Moments to one pound of static load, for one rail.

Engine	.....	Sum of positive bending moments	909,631.00	inch pounds	
--	.....	-- of P.B.M. per pound of static load	10.34	--	--
--	.....	-- of negative bending moments	231,329.00	--	--
--	.....	-- of N.B.M. per pound of static load	2.63	--	--
Tender	.....	-- of positive bending moments	576,368.00	--	--
--	.....	-- of P.B.M. per pound of static load	10.11	--	--
--	.....	-- of Negative bending moments	147,035.00	--	--
--	.....	-- of N.B.M. per pound of static load	2.58	--	--
Locomotive..		-- of positive bending moments	1,485,999.00	--	--
--	.....	-- of P.B.M. per pound of static load	10.25	--	--
--	.....	-- of negative bending moments	378,364.00	--	--
--	.....	-- of N.B.M. per pound of static load	2.61	--	--
--	.....	-- of wheel effects	1,864,363.00	--	--

P. H. DUDLEY'S STREMMATOGRAPH TESTS SEPTEMBER 27, 1901.

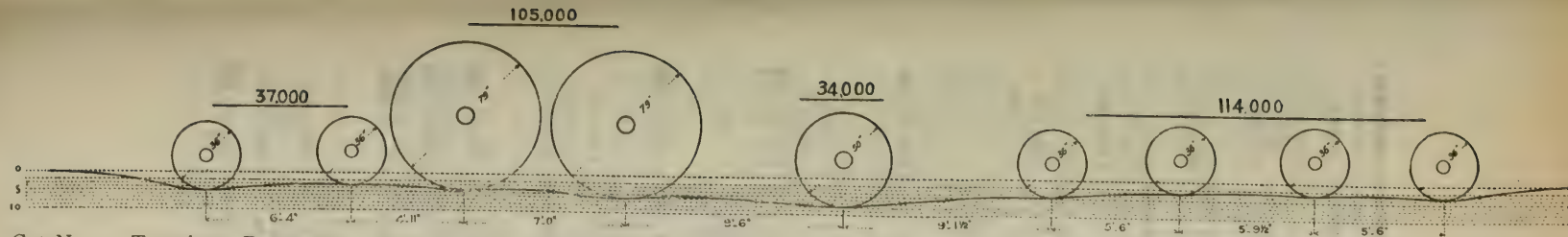
No.362. Track, No. 2. Location, West Albany Tower. Rail, 5-1/8 inch, 80-lb. Moment of inertia, 28.5 4th power inches. Crossties. Length, 8 feet. Width, 9 inches. Thickness, 6 inches. Wood, Y.P. Weight, 155 lb. No. 20 per 33-foot rail. Average weight of superstructure per yard 450 lb. Three-tie supported joints, 36-inch splice bars. Gravelballast. Train No. 51, EMPIRE STATE EXPRESS. Number of cars, 5. Weight, 550,000 lb. Locomotive No. 2985. Weight 290,000 lb. Speed 35 miles per hour. Temperature, 82° Fahr. Remarks, counterweight front driver up over stremmatograph.

The apparent mean unit fiber-stresses in the base of one rail were as follows in pounds:-

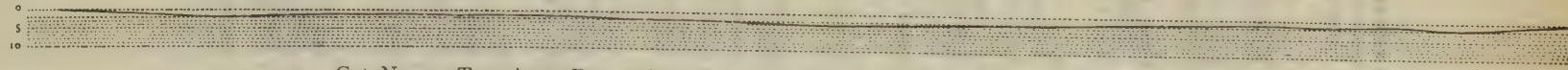
NOTE -- Pusher working moderately.	Per Wheel.	Per wheel base of			Per Pound of wheel Base of	Wheel effects	
		Drivers and trucks of engine, tender and cars.	Engine and tender.	Locomotive and cars.	Drivers and trucks of engine, tender and cars.	Positive bending moments under wheels. inch-pounds.	Negative bending moments between wheels inch-pounds.
Extra wave preceding truck wheel	0	--	--	--	--	--	--
Compression in front of truck wheel	1,417	--	--	--	--	--	16,154
LOCOMOTIVE Engine Truck Tension under front truck wheel	12,754	--	--	--	--	145,396	--
Compression between front and rear truck wheel,	4,015	26,571	--	--	1.246	--	45,771
Tension under rear truck wheel	6,377	--	--	--	--	72,698	--
Compression between truck wheel and front driver	4,015	--	--	--	--	--	45,771
Drivers Tension under front driver	12,754	--	--	--	--	145,396	--
Compression between drivers	4,724	43,931	101,680	--	0.926	--	53,854
Tension under main driver	20,785	--	--	--	--	236,949	--
Compression between main driver and trailing wheel	7,322	--	--	--	--	--	83,471
T.W. Tension under trailing wheel	24,328	31,178	--	--	1,610	277,339	--
Compression between trailing and front wheel of tender	6,377	--	--	152,234	--	--	72,698
Tender F. T. Tension under front tender wheels	15,825	--	--	--	--	180,405	--
Compression between tender wheels, front truck	2,362	29,879	--	--	1,090	--	26,927
Tension under rear tender wheel front truck	6,614	--	--	--	--	75,400	--
Compression between front and rear tender trucks	3,779	--	50,554	--	--	--	43,081
R. T. Tension under front tender wheel rear truck	6,850	--	--	--	--	78,090	--
Compression between wheels of rear tender truck	2,362	20,675	--	--	0.780	--	26,927
Tension under rear tender wheel	7,684	--	--	--	--	87,598	--
Compression between tender wheel and first car wheel	3,779	--	--	--	--	--	43,081

Reduction of sum of positive and negative bending moments to one pound of static load, for one rail.

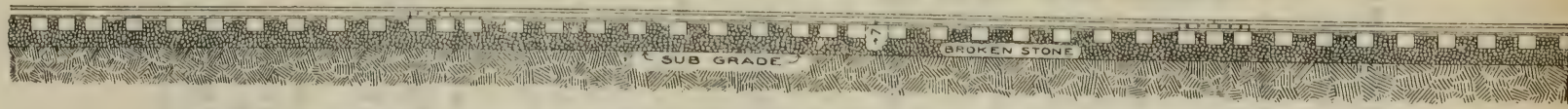
Engine.....	Sum of positive bending moments	877,778.00	inch-pounds	
-- ..... --	of P.B.M. per pound of static load	9.97	--	--
-- ..... --	of negative bending moments	281,370.00	--	--
-- ..... --	on N.B.M. per pound of static load	3.20	--	--
Tender.....	-- of positive bending moments	421,493.00	--	--
-- ..... --	of P.B.M. per pound of static load	7.39	--	--
-- ..... --	of negative bending moments	154,825.00	--	--
-- ..... --	of N.B.M. per pound of static load	2.72	--	--
Locomotive.	-- of positive bending moments	1,299,271.00	--	--
-- ..... --	of P.B.M. per pound of static load	9.65	--	--
-- ..... -	of negative bending moments	436,195.00	--	--
-- ..... --	of N.B.M. per pound of static load	3.01	--	--
-- ..... --	of wheel effects	1,735,466.00	--	--



Cut No. 1—Transitory Depression Under the Moving Locomotives or Cars From the "Trackmen's Surface" of the Rails, Cross-Ties, Ballast and Sub-Grade to Their Loaded Position in the Equilibrium Depression, with Specific Deflections Under the Wheel Contacts.



Cut No. 2—Transitory Depression of the Sub-Grade Under the Load of the Locomotive.



Cut No. 3—"Trackmen's Surface" on a Longitudinal Section of the N. Y. C. & H. R. R. R. Standard Track, 1903.

THE AUTHOR'S SECOND AND THIRD PRINCIPLES OF RAILROADS, ILLUSTRATED BY DIAGRAMS INDICATING THE TRANSITORY DEPRESSIONS OF THE TRACK UNDER MOVING LOCOMOTIVES AND CARS.

Test No. 362. Locomotive No. 2985. N. Y. C. & H. R. R. R. 80-lb. Rails. Date, Sept. 27, 1901.

The upper broken line in Cut No. 1 shows the normal surface of the rail when unloaded—as it appears to the trackmen—illustrated by the longitudinal section of the track in Cut No. 3.

The upper broken line in Cut No. 2 shows the normal surface of the sub-grade when unloaded, while the full line underneath indicates the depression to carry and distribute the load of the locomotive.

The undulatory full line under the wheels in Cut No. 1 indicates the Specific Deflections of ⅛ to ¼ of an inch of the surface of the rails, cross-ties, ballast, and sub-grade, to their lower loaded position in the Equilibrium Depression, for conjoint action and support to carry and distribute the load of the locomotive.

The undulatory line in Cut No. 1 also represents the surface of the rails, as the equilibrium of the forces between the resistance of the permanent way and the super-imposed load of the moving locomotive.

The unit fiber strains in the rails in starting or recovering from the Equilibrium Depression are small, and indicate the looseness and flexibility of the superstructure in the ballast and the elasticity of the sub-grade.

The maximum unit fiber strains in the rails occur in the Specific Deflections under the wheels in the Equilibrium Depression.

The compression of the sub-grade forms about one-fourth to one-fifth of the total amount of the subsidence of the surface of the rails from their unloaded to their loaded position.

The diagrams show that the portions of the rails occupied by the driving wheel base in the lower loaded position of the Equilibrium Depression are restrained, in front by the forward truck wheels, and in the rear by the tender wheels.

The lines in Cuts Nos. 1 and 2 are spaced .04 of an inch, or one millimeter, except the upper and second lines, which are double spaced.

P. H. DUDLEY.

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Note Sur Le Joint Asymetrique	M. H. Bouchard	Revue Generale des Chemins de Fer	Jan., 1909
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Character, Distribution, Stresses, etc., in Rails	M. L. Schlussel	Soc. Ing. Civ. de France	Sept., 1909
Stresses in Rail Sleepers	J. D. W. Ball	Eng. Rev., London	Dec. 15, 1911

Appendix N.

THE TESTING OF RAILS.

By R. Scheibe, Councillor.

(Zeitung des Vereins Deutscher Eisenbahnverwaltungen.)

Bulletin of the International Railway Congress Association, Vol. XXVI, No. 4, April, 1912.

The valuable theoretical article about the quality co-efficient of the metal used for the track and rolling stock of railways published in the *Zeitung des Vereins Deutscher Eisenbahnverwaltungen* for 21 December, 1910*, is worthy of special attention, taking into consideration the economic importance which the question of testing rails and wheel tires has for all administrations.

The use of the so-called quality co-efficient (i. e., ultimate tensile strength multiplied by elongation), was specified by the German Verein when the observations were started in 1903 for obtaining statistics of the wear of rails. It was measured for this purpose, but is not considered by all administrations to be a satisfactory basis in practically estimating the good quality of rails.

Taking into consideration the generally-felt want of better wear-resisting rails for special purposes, the question of the *toughness* of the steel, which is theoretically closely connected with the power to resist wear (that is, the resistance to the tearing away of small particles of the rail), will in the future naturally be of greater importance than has hitherto been the case; this quality is at present only estimated in a certain way from the results of impact tests and from the elongation in the tensile tests.

The tensile tests, even if the quality co-efficient is taken into consideration, cannot serve in practice as a basis for determining the resistance of the rail steel to wear and tear; this is clearly shown, inter alia, by the statistical tables published by the *Verein* in 1908, containing the statistical records of the behavior of rails with special reference to the nature of the material.

The ball-hardness test can be used just as little as the tensile test in order to determine the power to resist wear; it was attempted to prove this in the *Organ für die Fortschritte des Eisenbahnwesens*, 1909, No. 19*.

It has already been recognized repeatedly that it is impossible, using the present specified reception tests, to determine the important properties

*See summary of this article, given below.

sufficiently well to have proper information about each of them, including the power to resist wear; consequently, the following proposals have been made with the object of *directly measuring the power to resist wear:*

(1) In the above-mentioned paper published in the *Organ* for 1909, it is proposed to test the rails at the rolling mills by means of a grinding machine consuming a definite amount of electrical energy, so as to determine their resistance to wear;

(2) Dr. Saller, engineer, member of the board of the Bavarian State Railway, proposes in the paper mentioned to take the action of the sand blast on the rails as comparative basis for determining the resistance to wear. It is possible that this method may lead to usable results, when the proper basis for the comparison has been determined;

(3) Dr. Preuss, engineer, testing department of the technical high school at Darmstadt, has already begun experiments with the object of determining the resistance to wear of the rails by steel wheels rolling and gliding at the same time.

The empirical determination of the bases of any method for elucidating the relations which exist between the resistance to wear and the other properties of rails, so that the method may be correct in theory and easily applicable in practice, so that reliable results may be obtained, presents such great difficulties that it would be very advisable *that such investigations should be started by as many different parties as possible.*

Such multiple investigations would contribute more or less towards reducing the time necessary for the preliminary work, its scientific utilization and the determination of the conclusions to which it would lead.

* * * *

SUMMARY OF THE ABOVE-MENTIONED ARTICLE BY DR. H. SALLER, BAVARIAN STATE RAILWAY, PUBLISHED IN THE "ZEITUNG DES VEREINS DEUTSCHER EISENBAHNVERWALTUNGEN," 21 DECEMBER, 1910.

At the eighth session of the International Railway Congress at Berne (July, 1910), it was urged that uniform international specifications should be drawn up for the iron and steel used for railway purposes, and the next session of the Congress is to receive a report, drawn up conjointly with metallurgists, about the state and progress of the work of the International Association for Testing Materials, of comparing the specifications of iron and steel in the different countries.* It is a fact that the greatest strains which the material of the track and partly also that of the rolling stock has to suffer, are produced *dynamically,* by shocks, blows and oscillations. As regards the track, not only do the blows affect the rails as a whole, but also and especially the rolling surface of the rails. In the case of the rolling surface of the rails, these blows act like local hammering, leading to slight permanent deformation (apart from

*See Bulletin of the Railway Congress, number of June, 1911, p. 609.

the file-like action of the braked and skidding wheels.* The same applies to the case of the braked wheel tire. . . .

Some administrations are satisfied with specifying minima, which must be observed, for the ultimate tensile strength f, also for the contractions of area c in percentages of the original cross-section, or for the elongation l in percentages of a given length, or also for both the latter. Other administrations combine these values, evidently thinking that there must be a proportion between these values, to a "quality coefficient," and this combination can be effected in many different ways. We find specifications with minimum values for fl, for f^2l, for $f+l$, for $f+c$ (this very frequently),† for $f+2l$ and perhaps also for others.

This multiplicity of methods adopted can only remain justifiable as long as theory is unable to specify correct methods.

It has already been remarked that the greatest strains in the material of the track and of a great part of the rolling stock are produced *dynamically*. While the material requires great *tensile strength* in order to resist the static loads, it requires *toughness* in order to resist dynamic forces. The measure of this toughness in constructive materials is given by the expression $\frac{f^2}{E}$, or more accurately $\frac{T^2}{E}$, where f is the tensile strength or T its value at the elastic limit, and E is the modulus of elasticity. The modulus of elasticity is, however, equal to $\frac{elongation}{tension} = \frac{f}{l}$; accordingly the toughness is expressed by $\frac{f^2}{E} = fl$ or in other words by the product, tensile strength multiplied by elongation. Of the combinations given above, fl is accordingly the only one which is correct, according to dynamic theory. All other combinations are purely empirical. As regards the contraction of area c, first introduced by Kirkaldy and Wöhler and now frequently specified, Bauschinger especially has shown that it is not necessarily related to the elongation (which in this case is theoretically decisive). It is also theoretically only true to a limited extent, if it is assumed that the tensile strength must decrease in the same ratio in which the toughness increases. The tensile strength is on the contrary a very essential factor of the toughness itself, and the expression

*It was proposed recently, in order to test the material from this point of view, to make direct grinding tests by means of carborundum wheels (see article in the Organ, 1909, below). It may be suggested whether simple tests with the sand blast might not be of use from this point of view; only experiments can decide this point. The action of the sand blast seems to resemble both the filing and the grinding action; as there would be hardly any difficulty in procuring sand of uniform quality, there would be a sufficient uniformity in such tests, probably greater than in grinding tests, and the results would probably be recognizably dependent on the toughness and the brittleness of the material. Such sand blast tests would certainly not be costly, and might give accurate results with the help of the balance.

†Attention is drawn to the practical objections to this combination, which is very frequently adopted, by Professor Frank in the Organ, 1890 (account of strength tests of mild-steel rails). The supplier can increase the ultimate tensile strength more easily than the contraction, and with the practical result that the toughness suffers.

given for the latter contains the tensile strength squared.* It is, however, a different question in practice, to what extent it is necessary to reduce the elasticity, with increasing tensile strength, in the manufacture of the material. Experience shows that toughness is reduced with increase of tensile strength.†

Actually this product fl is already now frequently used in judging track metal.

The theoretical development of the quality co-efficient fl is based on the validity of Hooke's law, and accordingly this quality co-efficient is theoretically only valid within the limits of that law. According to Bach, and others, this law can be assumed to be very nearly true in the case of those constructive materials which are chiefly used for track and rolling stock, namely wrought iron, steel and wood, while it is not true in the case of many other constructive materials, for instance cast-iron. But even in the case of the former materials, Hooke's law is only true within certain limits and the expressions fl, if applied for conditions near fracture instead of within the elastic limit, has no theoretical signification. It is, of course, clear that it may be assumed that the deformations which are continually being produced in the track and rolling stock are, as a rule, entirely within the elastic limit or at least within the flow limit, as any greater and permanent deformations would necessarily result in fracture within a comparatively short time, as the forces in this case are repeated very frequently.

Now the elastic limit (and accordingly probably also the proportionality limit) is not unalterable; it can be increased by repeatedly loading between zero and an upper stress limit corresponding to the elastic limit or exceeding it slightly, and in this way the material can to a certain extent be brought to the so-called "constant state," in which the elasticity is nearly perfect. Those are the conditions which approximately exist in the case of railway work. But this increase of the proportionality limit, which makes it possible to increase the "hardness" which is practically utilizable, and perhaps to bring it nearer the ultimate fracture limit, seems to involve an appreciable reduction in the elongation and consequently a reduction in the power to resist shock.

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SUMMARY OF THE ABOVE-MENTIONED ARTICLE BY MR. R. SCHEIBE, PUBLISHED IN THE "ORGAN FUR DIE FORTSCHRITTE DES EISENBAHNWESENS," I OCTOBER, 1909.

The urgent need of obtaining rails having greater resistance to wear, especially for points and crossings as well as for the outer rails on

*The assumption that the wear of rails is, as a rule, directly proportional to their hardness, is hence frequently quite justified. See Organ, 1890, page 14, where Post found that with rails having an ultimate tensile strength of 65 kilograms per sq. millimetre (92,448 lbs. per sq. in.) a weight of 381 grams (0.840 lb.) was worn away, while under the same condition, with rails having an ultimate tensile strength of 50 kilograms per sq. millimetre (71,114 lbs. per sq. in.), the corresponding amount was 485 grams (1.069 lb.).

†In the case of ingot-iron boiler plate, Bach found that the toughness only began to be reduced when the ultimate tensile strength began to exceed 38 kilograms per sq. millimetre (54,047 lbs. per sq. in.).

curves, and of recognizing this quality with certainty before using the rails, leads to the proposal seriously to consider methods of testing the resistance of the rails to wear by grinding tests, and to undertake preliminary tests in order to develop a suitable method of carrying out such tests.

The impact, tensile and Brinell hardness tests will always remain the chief tests specified for rails; but the grinding test, particularly if combined with the microscopic etching tests, will be a valuable supplement to these tests, both from the economic and the technical points of view.

Although the objection may be raised, with justice, that grinding the head of the rail by means of say a carborundum wheel does not correspond to the effect actually produced by the action of the tires, yet this system of testing at present most closely approximates to the truth, and such experiments, carried out extensively, may lead to utilizable results. . . . The author then gives a description of the experiments which have been made according to his method and of their results, and draws the following conclusions:

Owing to the defects of the grinding appliances used for obtaining the results given in the preceding table, and of the methods of carrying out the tests, we will not attempt the scientific interpretation of the facts observed, namely, the difference of hardness at different points in the cross-section of the rail, different behavior of the steel when attacked parallel or at right angles to the direction of rolling, changes in the grain produced by the heat produced by the grinding (the surface becoming colored blue), smaller resistance to wear at the rolling surface than at the sides of the head, different resistance to wear if the test piece is cooled by a quick or a slow current of air, etc.

Nevertheless it may be assumed that new tests of grinding, carried out on accurate scientific principles, and combined with microscopic etching tests, will throw light on the question generally and in particular on that of the relation between ultimate tensile strength and resistance to wear, and that in course of time they will make it possible to deduce a method of testing the resistance to wear of rails which will be of value to railways; for it is possible that rolling mills may be able to satisfy any requirements specified from this point of view.

Number	Index Number in statistics.	ADMINISTRATION.	Ultimate tensile strength, in kilograms per square millimetre (in lb. per square inch).	Rolling load producing a reduction of 1 millimetre in the height of the rail, in millions of tons (in millions of English tons per inch).	Quality coefficient: tensile strength and elongation.
1	2	3	4	5	6
1	11	Baden State Railway.....	51.7 (73,532)	22.0 (550)	1,188.8
2	24	Baden State Railway.....	79.9 (113,640)	42.5 (1,062.4)	1,158.5
3	68	Bavarian State Railway.....	**53.9 (76,661)**	**24.7 (617.5)**	**243.0**
4	80	Bavarian State Railway.....	79.6 (113,214)	38.9 (972.4)	1,155.0
5	113	Alsace-Lorraine State Railw'y	60.3 (85,764)	57.7 (1,442.4)	301.5
6	115	Alsace-Lorraine State Railw'y	**74.6 (106,102)**	**62.5 (1,562.4)**	**894.7**
7	122	Breslau directorate.....	55.9 (79,505)	40.4 (1,009.9)	1,319.0
8	125	Breslau directorate.....	58.3 (82,919)	36.2 (904.9)	1,224.0
9	127	Essen directorate.....	80.5 (114,494)	19.3 (482.5)	604.4
10	131	Essen directorate.....	57.8 (82,208)	19.6 (490)	1,070.4
11	149	Frankfort directorate.....	58.0 (82,492)	77.4 (1,934.9)	1,339.4
12	152	Frankfort directorate.....	66.5 (94,582)	50.0 (1,249.9)	1,064.0
13	155	Hanover directorate.....	80.5 (114,494)	29.1 (727.5)	604.4
14	164	Hanover directorate.....	57.8 (82,208)	19.4 (485)	1,070.0
15	178	Saxon State Railway.....	**74.4 (105,818)**	**29.0 (725)**	**1,324.0**
16	182	Saxon State Railway.....	66.2 (94,155)	19.4 (485)	1,364.0
17	194	Wurtemberg State Railway..	58.5 (83,203)	34.4 (859.9)	1,240.0
18	196	Wurtemberg State Railway..	61.3 (87,186)	33.3 (832.4)	1,115.0
19	225	Austrian State Railway.....	70.1 (99,702)	80.1 (2,002.4)	1,262.0
20	229	Austrian State Railway.....	51.1 (72,679)	92.3 (2,307.4)	1,278.0
21	233	Austrian State Railway.....	**50.3 (71,541)**	**70.8 (1,769.9)**	**1,157.0**
22	234	Austrian State Railway.....	**47.3 (67,985)**	**70.8 (1,769.9)**	**263.0**
23	273	Austrian Southern Railway..	**74.8 (106,387)**	**19.5 (487.5)**	**1,122.0**
24	275	Austrian Southern Railway..	85.9 (122,174)	14.6 (365)	970.7
25	278	Austrian Southern Railway..	76.4 (108,662)	14.5 (362.5)	954.0
26	280	Austrian Southern Railway..	**78.0 (110,938)**	**11.2 (280)**	**733.0**
27	282	Austrian Southern Railway..	85.9 (122,174)	14.5 (362.5)	816.1
28	323	Hungarian State Railway....	65.4 (93,017)	62.0 (1,549.9)	1,046.4
29	332	Hungarian State Railway....	63.1 (89,746)	108.4 (2,709.8)	1,167.3
30	337	Hungarian State Railway....	**74.5 (105,960)**	**271.1 (6,777)**	**1,043.0**
31	338	Hungarian State Railway....	67.3 (95,720)	141.4 (3,534.8)	1,009.5
32	344	Hungarian State Railway....	65.0 (92,448)	47.8 (1,194.9)	1,202.5

Remarks.—No definite relation between the figures in columns 4, 5 and 6 can be recognized. Nos. 6 and 26, as well as 15, 23 and 30, have similar ultimate tensile strengths and quality coefficients, and at the same time show great differences in resistance to wear; while Nos. 9, 10 and 23, show nearly the same resistance to wear, while the tensile strengths and quality coefficients are very different. The greatest and least resistances to wear (Nos. 26 and 30) occur in cases where the tensile strengths are nearly the same, while the quality coefficients are very different.

REPORT OF COMMITTEE XVI—ON ECONOMICS OF RAILWAY LOCATION.

A. K. Shurtleff, *Chairman;* R. N. Begien, *Vice-Chairman;*
F. H. Alfred, Fred Lavis,
A. C. Dennis, F. W. Smith,
C. P. Howard, H. J. Simmons,
F. W. Green, Walter Loring Webb,
P. M. LaBach, M. A. Zook,
Committee.

To the Members of the American Railway Engineering Association:

The Committee on Economics of Railway Location has held but one meeting during the year, this being at Chicago, May 27, 1912. Messrs. Begien, LaBach, Zook and Shurtleff were present. Letters explaining absence were received from Messrs. Dennis, Green, Howard, Simmons and Webb. Owing to the small attendance the Committee confined itself to the general consideration of data necessary to properly analyze operating expenses in connection with the problem of economic location.

The Baltimore & Ohio Railroad Company has made some extensive tests with a dynamometer car, and your Committee appreciates the paper presented by Mr. R. N. Begien, its Vice-Chairman, which is made an appendix to this report and recommends the adoption of conclusions therein, with reference to train and curve resistance, to take the place of Conclusions 2, 3, 4 and 7, as given in the 1911 Manual.

The Chairman of your Committee has made a study to determine the approximate general laws affecting such Maintenance of Way accounts as are influenced by changes in physical characteristics of locations and presents the results of this study for the consideration of the Association. It is not assumed that the analysis of the accounts for the 53 railroads shown in the table gives the correct cost per mile of main track, but it is believed that for the major portion the figures are within reasonable proximity of the truth, and that the individual diagrams show with sufficient accuracy the general law of ratios of increased cost for a fixed unit of traffic to the portion of expense due to age or decay.

The conclusions presented are recommended for adoption, believing that the application of the formulas therein to the normal annual charge for each account will eliminate considerable of the guesswork of the past. The ratios of cost per mile of side track to mile of main track on any particular line can be estimated without too great an element of guesswork, and in the average case it will not be found far from the suggested value in the table. With these conclusions adopted your Committee has a way opened for the further study of questions entering into economics of location.

ANALYSIS OF MAINTENANCE OF WAY AND STRUCTURE ACCOUNTS.

The majority of the problems of Economics of Railway Location deal only with main track questions, although an occasional problem introduces the consideration of sidetracks. It is therefore necessary to analyze and separate certain of the primary operating accounts between costs for main track and costs for sidings, particularly those accounts covering Maintenance of Way and Structures.

Great difficulty has been found in obtaining the necessary information from the railway companies to aid in the proper analysis of the questions. Only three or four railroads out of the many asked for information have attempted to give any data to aid in the digest of this particular question. However, the question has been studied on one large system of nearly 8,000 miles of main tracks and does not vary materially from the ratios of costs per mile of main and side tracks from the other three roads. The figures cover a period of four years and are used in the following analyses, believing them to represent a fair and reasonable average of the relative costs of maintaining main and side tracks for most of the railways of the United States. The figures will not apply to roads lying entirely within a dense manufacturing or mining district where the necessary mileage of side track nearly equals or sometimes exceeds the main track mileage, and the switching mileage is so heavy as to make the tonnage over the side tracks exceedingly large. The methods of this analysis can be followed in such a case, using the ratios of costs that have been found proper for the heavy switching traffic on the industrial sidings.

The following gives only the accounts which are particularly due to both main and side track usage.

Account 1.—*Superintendence of Way and Structures.* One mile of side track requires practically one-third the cost of one mile of main track.

Account 2.—*Ballast.* One mile of ballasted side track averages only about one-fourth the cost of one mile of ballasted main track. This factor is a difficult one to reach logically and is a matter of judgment. No detail figures have been obtainable, as usually only a minor portion of side tracks are ballasted and not all main tracks.

Account 3.—*Ties.* The number of renewals per mile of side track for four years averaged about 70 per cent. of the number per mile of main track. The side track renewals embraced No. 2 ties as well as No. 1, and the average cost per side track tie was about 70 per cent. of the cost per tie for main track, making the total charge per mile of side track practically one-half of the cost per mile of main track.

Account 4.—*Rails.* Main line rail was relaid by new rail, re-rolled rail or good relayers of heavier section, in all cases the renewal portion of the charges being only the tonnage equal to the weight of the released rail at the charge per ton for the material replacing it. Side

track renewals were from relayers only and charged out on the above principle according to the form prescribed by the Interstate Commerce Commission. The arbitrary credit for relayers released and charge for same used was practically 75 per cent. of the cost of new rail. Scrap released was credited at approximately market value. The average charges per mile of side track for rail renewals was about 25 per cent. the cost per mile of main track.

Account 5.—*Other Track Material.* Practically 37 per cent. of this account was account of frogs and switches, the major portion being to *turnout* frogs, hence due entirely to side tracks, although many existed in the main track. A careful analysis shows that one mile of side track costs practically the same as one mile of main track for this account, due almost wholly to the costs of turnout frogs and switch points.

Account 6.—*Roadway and Track.* The cost per mile of side track averages about one-third the cost per mile of main track. This is due not only to the lower grade of maintenance of side track, but to the fact that many items charged into this account are principally main track items, for example, ditching, bank widening, track walkers, cutting weeds on right of way, etc.

Account 9.—*Bridges, Trestles and Culverts.*

Account 10.—*Over and Undergrade Crossings.* Occasionally a small portion of these two accounts is chargeable to side tracks, but for the majority of cases the amount is so small as to be negligible in economic calculations.

Account 18.—*Roadway Tools and Supplies.* One mile of side track requires about one-third the cost of one mile of main track.

In the remaining accounts of Maintenance of Way and Structures the side track mileage rarely affects the amount of the account and can be neglected in economic calculation. The main track portion of these accounts per mile of main track can be obtained by dividing the total charge to each account by the equivalent main track mileage, the latter being the total main track mileage plus the product of side track mileage by the proper per cent. of cost per side track mile for the given account.

The above accounts are all materially affected by volume of traffic except Account 2, Ballast, and Accounts 9 and 10, Bridges, Culverts, Over and Under Grade Crossings.

The train mile has been commonly used as a traffic unit in economic studies in the past, but it is illogical to use this unit as a measurement of wear and tear on the track owing to the wide limits in weights of trains that can be handled by the same locomotive on districts of different gradients. A train with gross weight of 2,000 tons will cause about double the wear and tear on the structure that would be caused by one of half the weight. The ton mile would be the best unit considering total weights on the rails if freight traffic only passed over the track, but passenger traffic also must be considered and owing to the higher velocity of trains the damage done per ton of passenger train is greater and the labor

of maintaining track for the higher velocities is increased. With velocities equal, the damage done to track will vary about directly proportional to the load per axle and one ton of locomotive will create more disturbance to track than one ton of car and contents.

The following gives some average axle loads for the heaviest types of modern locomotives and for average loading for cars. It will be many years before the average locomotive loading reaches these figures, while the average car loading will probably increase:

	Average load per axle.
Passenger Service.	
Atlantic Locomotive	39,100
Pacific Locomotive	37,800
10-Wheel Locomotive	22,000
Average Passenger Train Car	22,000
Freight Service.	
Mikado Locomotive	48,500
Consolidation Locomotive	44,600
Mallet Comp. Locomotive	42,300
50-ton Capacity Gondola Car, loaded one way; return empty.	22,500
Average 35 tons per car of freight train (above present average)	17,500

The present average of load per axle of freight and passenger locomotives is less than double the average load per axle of train.

In studying average maintenance expenses by divisions for a period of years on the large system previously mentioned it appeared that the best unit of traffic measurement of expense was what we will term the equivalent ton mile. The total equivalent ton miles would be the sum of the following:

Double the freight locomotive mileage times average weight per locomotive.
Four times the passenger locomotive mileage times average weight.
Total freight ton miles (cars and contents).
Double the passenger ton miles (cars and contents).

This unit considers that one ton of passenger car does double the injury of one ton of freight car, and that one ton of locomotive affects the track as much as two tons of the train back of the locomotive. This unit of measurement even best fits the increase of maintenance of buildings due to increase of traffic and consequent increase in number and size of buildings. Passenger traffic demands a higher type and better grade of maintenance than freight, and even a better type of shop buildings for repair.

With the exception of Account 4, Rails, there is a minimum expense for the accounts affected by volume of traffic due to depreciation and decay. This expense must be met to keep the road in shape for

operation. The increase in expense above this minimum is practically directly proportional to the equivalent ton mileage passing over the tracks. There may be a slight loss of rails by corrosion, but its effect on the general account cannot be noticed and the cost can safely be considered directly proportional to the equivalent ton mileage.

Criticism may be made of adopting a traffic unit that involves the estimating of passenger train tonnage. Nothing can be done of value if the work of the Committee is to be based in the terms of statistics as kept at the present time. Net ton miles, freight and passenger train car mileage is kept, also road engine mileage separated between freight and passenger service. Weights of locomotives are a matter of record. The estimating covers the assumption of an average weight for empty freight cars, which at present is about 18 tons, and an average weight per car and load of passenger train cars. At the present time 44 tons per passenger train car of the average train will not lead to great error, and the average passenger train of the United States has approximately 5.3 cars per train. This last figure is not necessary for use where passenger train car mileage is available.

Early in the present year the Interstate Commerce Commission published a pamphlet, "A Preliminary Abstract of Statistics of Common Carriers for the Year Ended June 30, 1911." The information in this pamphlet is more complete with reference to operating data of individual roads than has heretofore been published.

The table herewith showing the items of costs of the maintenance accounts affected by traffic is deduced from data given by the Commission, using the ratios of costs per mile of side track as outlined to reduce to cost per mile of main track only. As only average weights of locomotives, excluding tender, were given, two-thirds of the weight was added to cover weight of tender and the same weight of engine was assumed for both passenger and freight service. The ton mileage was worked from net ton mileage and the mileage of the two classes of cars and road engines.

There is no attempt to place the cost of ties in dollars per mile of track as there is probably no account in which there is a wider variety of materials or unit costs than in ties. Climatic conditions affect the tie question, particularly noticed when comparing the roads of the South with those of the North. It is evident that the roads using either properly treated woods or timber of a high grade, and protecting the ties from mechanical wear by heavy tie plates with good bearing area, are receiving good returns because of the practice.

In all of the accounts it must be recognized that some of the roads were above the normal in the various accounts and other roads below. The graphical charts show the points for the fifty-three roads and also a line showing the practical mean of all of the points. This line can be considered as representing the average present day cost for the given items. Taking the data from several years' operation of a railway, the following

RAILROAD	Equivalent 1,000 Ton Miles per Mile Main Track			Costs per Mile Main Track						Renewals per Mile of Main Track		
											Ties	
	Freight	Passenger	Total	Acct. 1 Supt.	Acct. 6 R.W. & T.	Acct. 18 R.W.Tools Etc.	Acct. 4 Rails	Acct. 5 Other Track Material	Acct. 16s Building	Tons Steel	No.	Average Cost
Pennsylvania R. R.	8,920	4,695	12,724	$142	$918	$ 28	$129	$131	$359	11.51	248	$1.00
D. L. & W.	7,338	4,532	11,870	111	619	33	301	152	294	20.22	209	.83
Pennsylvania Co.	7,629	4,106	11,735	109	774	12	107	101	265	3.86	228	1.13
P. & L. E.	8,269	2,771	11,040	136	1,282	40	171	161	348	24.86	384	1.17
N. Y. C. & St. L.	8,898	2,120	11,018	71	665	20	119	101	121	11.29	367	.78
P. & R.	7,888	3,627	11,515	100	681	26	130	117	279	12.22	287	.87
Vandalia	3,817	2,900	6,717	105	455	13	67	51	95	2.38	285	.65
L. S. & M. S.	6,060	4,412	10,472	77	824	48	90	105	260	5.78	289	1.12
N. Y. C. & H. R.	5,451	5,062	10,513	119	619	23	165	107	279	15.60	260	.85
C. R. R. of N. J.	6,263	3,996	10,259	71	714	14	128	120	457	16.24	242	.94
Northern Cen.	6,500	3,258	9,758	133	743	20	144	138	677	9.61	215	1.42
N. & W.	7,652	1,766	9,418	51	517	32	147	106	167	11.06	380	.57
P. C. C. & St. L.	5,979	3,368	9,347	100	704	9	97	85	161	3.39	205	1.20
Erie	5,766	3,269	9,045	82	569	19	105	80	167	18.02	233	.84
Lehigh Valley	6,405	2,280	8,685	76	469	17	109	70	196	7.54	153	.98
B. & O.	6,053	2,799	8,852	83	598	11	92	52	164	6.37	170	.93
P. B. & W.	3,478	5,558	9,036	141	678	26	56	93	293	5.73	310	.89
D. & H. Co.	6,151	2,311	8,462	46	377	15	77	77	134	5.00	176	.73
C. C. C. & St. L.	4,720	3,424	8,144	68	496	16	53	87	187	6.04	327	.87
C. & O.	5,688	1,770	7,458	50	504	18	69	73	123	6.11	317	.64
Wabash	4,155	2,642	6,797	34	445	8	71	56	100	3.44	397	.59
C. & A.	3,897	3,001	6,898	57	532	12	42	82	136	5.68	275	.67
Illinois Cen.	3,965	2,341	6,306	60	486	18	44	62	158	4.36	258	.64
Long Island	805	5,651	6,456	125	525	25	25	43	251	2.30	195	.92
D. M. & N.	4,749	790	5,539	46	1,149	28	69	66	176	5.89	204	.44
C. & E. I.	3,846	1,779	5,625	58	253	7	28	47	63	3.00	123	1.07
Mobile & Ohio	4,077	1,392	5,469	41	364	12	38	54	88	4.36	476	.40
L. & N.	3,487	1,888	5,375	64	427	18	113	67	200	7.02	324	.68
S. P.; G. H. & S. A.	2,170	3,146	5,316	82	602	31	76	96	147	6.60	283	.57
A. T. & S. F.	2,603	2,536	5,139	90	564	28	55	56	160	7.01	302	.74
T. P.; O. S. L.; O.-W. R. R. & N. Co.	2,322	2,455	4,777	77	514	28	30	57	128	5.25	243	.78
N. C. & St. L.	2,739	1,931	4,670	52	607	14	42	47	115	2.74	519	.43
C. G. W.	2,526	1,898	4,424	84	342	7	17	43	78	16.59	441	.....
C. B. & Q.	2,351	1,943	4,294	62	454	8	69	26	126	15.01	337	.56
C. & N.-W.	2,269	2,074	4,343	41	407	8	46	35	112	4.58	227	.52
C. R. I. & P.	2,176	2,184	4,360	62	371	11	34	35	132	2.85	245	.79
Canadian Pac.	2,298	1,879	4,177	45	580	16	68	40	164	9.11	240	.40
M. K. & T.	2,072	2,063	4,135	47	434	16	11	45	83	3.00	420	.48
Southern	2,176	2,033	4,209	55	299	9	73	47	83	5.89	374	.49
C. St. P. M. & O.	2,118	1,953	4,071	40	367	8	59	34	106	6.24	262	.50
C. M. & St. P.	2,400	1,618	4,018	28	311	15	53	34	89	7.24	197	.54
Northern Pacific	2,074	1,935	4,009	59	501	11	28	30	79	3.17	404	.45
Great Northern	1,968	1,933	3,901	64	561	11	28	41	66	3.14	320	.52
St. L. & S. F.	2,030	1,908	3,938	70	335	14	21	37	76	2.67	396	.52
Pere Marquette	2,295	1,300	3,595	33	267	6	18	33	65	4.63	192	.66
Texas & Pacific	2,051	1,439	3,490	30	364	13	32	41	135	2.64	329	.50
Mo. P.; St. L. I. M. & S.	2,050	1,492	3,542	76	384	15	61	53	77	6.64	409	.53
D. & R. G.	1,845	1,685	3,530	73	493	21	21	31	69	1.80	283	.70
Y. & M. V.	1,932	1,125	3,057	65	468	28	35	66	118	3.19	430	.58
Seaboard Air Line	1,674	1,538	3,212	38	319	13	23	46	91	4.69	381	.35
Atlantic Coast Line	1,586	1,536	3,122	39	269	11	66	41	89	9.92	324	.41
M. St. P. & S. Ste. M.	1,788	1,293	3,081	17	246	7	2	16	53	1.75	234	.27
Cen. of Georgia	1,453	1,360	2,813	63	270	11	62	42	94	6.42	362	.43
Average cost per mile of side track in per cent of main track				33⅓%	33⅓%	33⅓%	25%	100%				

formula will give the average expense to maintain due solely to age and decay for the accounts where both decay and mechanical wear enter the question and using the tabular values for the functions as deduced from these statistics for 1911 the average expense for any volume of traffic per mile of main track can be estimated:

A = Total Main Track Mileage.
B = Total Side Track Mileage.
C = Average annual charge to the given account.
P = Proportional charge per mile of side track as compared with charge for main track only.
X = Annual charge per mile of main track to keep in condition for proper operation covering the amount due to age or decay.
R = Proportion of X representing the additional charge per mile of main track for each million equivalent ton miles per annum.
M = Million ton miles traffic per annum per mile of main track.
E = Charge per annum per mile of main track only, for the given account.

$$E = \frac{C}{A + BP} = X + MRX = X\,(1 + MR)$$

$$\text{Then } X = \frac{C}{A + BP + MR\ (A + BP)}$$

The values given for P and R in the tables with conclusions are suitable to determine average value of X for the great bulk of the railroads of the country, providing a sufficient number of years' data is used to produce a normal average. For the exceptional cases where a large portion of total track mileage consists of busy industry spurs and sidings, suitable values for P must be ascertained.

The data given for ties is based on a study of renewals on different divisions of the same line with widely varying traffic. On track where ties were of a high grade timber or creosoted and with a large proportion of ties protected by heavy tie plates, the renewals in main track were 6.5 per cent. of total in the track plus 0.3 per cent. for each million equivalent ton miles traffic. This figure appears to fit very closely the northern half of the United States where the roads have taken means to properly protect the ties. In the southern portion the per cent. due to decay will be greater, but by multiplying the proper percentage by the value .046 per million equivalent ton miles, the average renewals can be approximated for cases where proper methods are used to retard mechanical wear. Each locality can determine within reasonable limits the value of the constant renewals required due to decay for the available timbers.

Account 4, Rail Renewals, apparently costs about $11.00 per mile of main track for each million ton miles and requires about 1.1 tons of new rail for this traffic. This figure will answer under present conditions of rail renewals and checks very closely with some data gathered on the

equivalent ton mileage per mile of track during the life of 80-lb. tangent rail on a busy double track division. The maximum equivalent tons over any of the rail was 147 millions. The tangent rail released was in condition for relayers or for re-rolling and considering 110 million miles the average for this rail would make practically 1.1 tons per million equivalent ton miles.

According to custom the maintenance charges are only for the weight released less the arbitrary credit for the usable released material, although heavier section may be used for replacements. The relayers when used to replace still lighter section on districts of less traffic will further reduce the maintenance charge, as the rail finally released fixes the final distribution of total cost between Maintenance and Betterments. It is apparent that as the average weight of rail approaches the modern heavier section that betterments will absorb a less proportion of expense of rail renewals and maintenance charges; will be increased. Sufficient data is not at hand to show whether the heavier rail will withstand an equivalent increase in tonnage directly proportional to its weight. It can hardly be expected to do so as head wear determines the necessity of renewals where rail sections are sufficiently stiff for the axle loads. The cost of rail renewals will probably be found to bear a different relation to volume of traffic in a very few years.

The other Maintenance of Way and Structures accounts affecting main track are for all practical purposes independent of the volume of traffic. Most of them are dependent on either mileage of main track or mileage of road. Tunnels, Bridges and Culverts and Over and Under Grade Crossings are dependent on topography of the country and materials of construction and in comparing the relative economy of different locations the amount and character of tunnels and bridges on each must be considered in estimating the difference in maintenance costs.

The tables in the conclusions give the accounts under their respective headings. Other Maintenance of Way and Structures accounts may be ignored as they bear practically no relation to location.

Average values for any of these main accounts can be obtained from Interstate Commerce Commission Reports for the leading roads in all sections of the country.

The foregoing covers only the foundation of the work for analyzing the effect of changes in physical characteristics on Maintenance of Way and Structures accounts. It can be seen that distance affects nearly all of the accounts mentioned and that volume of traffic affects only a portion of them. Curvature affects only the rail renewals and roadway and track accounts with a very slight addition to tie renewals, providing that good substantial tie plates having large bearing area are used. It must be assumed that proper details of construction are used in the initial work in estimating relative values of different lines. Future study of the Committee should be to determine the effect of curvature on the accounts

mentioned and then take up the study with reference to Maintenance of Equipment and Conducting Transportation expenses.

The following are the conclusions with reference to the present study:

CONCLUSIONS.

Maintenance of Way and Structures:

1. The problems of economic location deal only with main track in the majority of cases, side tracks entering into the question only where differences in distance is so great as to necessitate additional side tracks.

2. The annual charge per mile of main track for any account embracing both main and side track can be approximated for any operated line by the following formula:

A = Total average main track mileage.
B = Total average side track mileage.
C = Average annual charge to the account.
P = Proportional charge per mile of side track as compared with charge per mile of main track.
E = Average annual charge per mile of main track only.

$$E = \frac{C}{A + BP}$$

The average value of P is shown in the table, but for roads located almost wholly within dense mining or manufacturing districts requiring an exceedingly large proportion of busy side and spur tracks the values would be higher and should be determined.

3. The accounts covering maintenance of main track do not all vary by the same general law, but vary most directly according to the following groups:

(a) Affected by both miles of track and volume of traffic.
(b) Affected by miles of main track.
(c) Affected by miles of road.
(d) Affected by local topographical features.

Therefore no single unit of measurement of relative maintenance expense is applicable to all accounts in comparing the relative economies of two locations. The tables show the groupings of the accounts under their proper heading.

4. One ton of passenger train does more damage to track than one ton of freight train and the locomotive creates more disturbance than an equal weight of cars and contents. Until data is available to correctly estimate the relative damage, it is recommended that the following ratios be used in estimating effect of traffic on the accounts in Group (a):

One ton of passenger car and contents produces approximately the effect of two tons of freight car and contents.

One ton of locomotive produces approximately the effect of two tons of the balance of its train.

The total ton mileage reduced to terms of ton miles of freight car and contents is termed the *equivalent ton mileage.*

Most of the accounts in Group (a) have a constant maintenance expense due to age and decay plus an additional expense depending on volume of traffic. This additional expense per mile of main track varies most directly with the *equivalent ton mile.* The equivalent ton mileage can be approximated by adding together the following:

Net freight ton mileage.

Double the freight locomotive mileage times average weight in tons.

Freight train car mileage times the average weight of empty cars (at present about 18 tons).

Double the passenger train car mileage times the average weight of car and contents (at present about 44 tons).

Four times the passenger engine mileage times the average weight in tons.

5. The average annual expense per mile of main track due to age or decay for the accounts in which this item enters can be approximated for any road by the following formula:

E = Charge per annum per mile of main track only.

X = Annual charge per mile of main track due to age or decay.

R = Proportion of X covering the additional charge per annum per mile of main track for each million equivalent ton miles.

M = Million equivalent ton miles per annum per mile of main track.

Then from above and equation in Conclusion 2.

$$E = X + MRX = X(1 + MR) = \frac{C}{A + BP}$$

$$X = \frac{C}{A + BP + MR(A + BP)}$$

Average values for P and R are shown in the tables.

ACCOUNTS AFFECTED BY MILES OF TRACK AND VOLUME OF TRAFFIC.

%	ACCOUNT	Avg. Values		1911 Avg. Values		REMARKS
		P	R	X	RX	
1	Superintendence	0.33	0.44	$18.	$ 8.	
2	Ties (Based on number used)	0.7	0.046	Varies	.....	Cost, quality and climatic conditions vary widely.
2	Ties (Based on Cost)	0.5	0.046	Varies	.....	Local conditions must determine value of X. Curvature affects charges but lightly where protected by proper plates and fastenings.
4	Rails	0.25	.....	0	.....	Present average annual charge per mile of main track is $11.00 per million ton miles or 1.1 tons new rails for same traffic. Curvature affects this account.
5	Other Track Material	1.	.....	0	.....	Present average annual charge per mile of main track is $10.00 per million ton miles. Affected slightly by curvature.
6	Roadway and Track	0.33	0.245	$200.	$49.	Affected by curvature.
16	Buildings	0.	2.4	10.	24.	Affected only where distance or increased volume of traffic makes additional buildings necessary.
18	Tools and Supplies	0.33	0.40	5.	2.	

ACCOUNTS AFFECTED BY MAIN TRACK MILEAGE.

No.	Account.	Remarks.
2.	Ballast	For full ballasted track this varies with the quality of ballast and cost laid down at side of track.
7.	Removal of Snow and Ice	Varies widely, depending on climatic conditions.
13.	Signals (Block Signals only)	Present average cost $125.00 per mile with average of one signal to the mile. Curvature may necessitate additional signals.
20.	Stationery and Printing	

ACCOUNTS AFFECTED BY MILEAGE OF ROAD.

11.	Grade Crossings, Fences, Cattle Guards and Signs	Mileage of main track affects this account slightly, but variation is most directly in proportion to miles of road.
12.	Snow Fences and Snow Sheds	Varies widely, dependent on climatic conditions.
14.	Telegraph and Telephone Lines	Varies slightly per mile of road, depending on number of wires.

ACCOUNTS AFFECTED SOLELY BY TOPOGRAPHICAL FEATURES.

8.	Tunnels	
9.	Bridges, Trestles and Culverts	The expense of these items depends on the number, size and character of the structures on each location.
10.	Over and Under Grade Crossings	

REVISION OF MANUAL.

Your Committee recommends that Conclusion 2, page 436 of the Manual, be changed to read: Numerous tests demonstrate that there is no absolute value for train resistance. For practical purposes freight train resistance can be considered constant between velocities of 7 and 35 miles per hour.

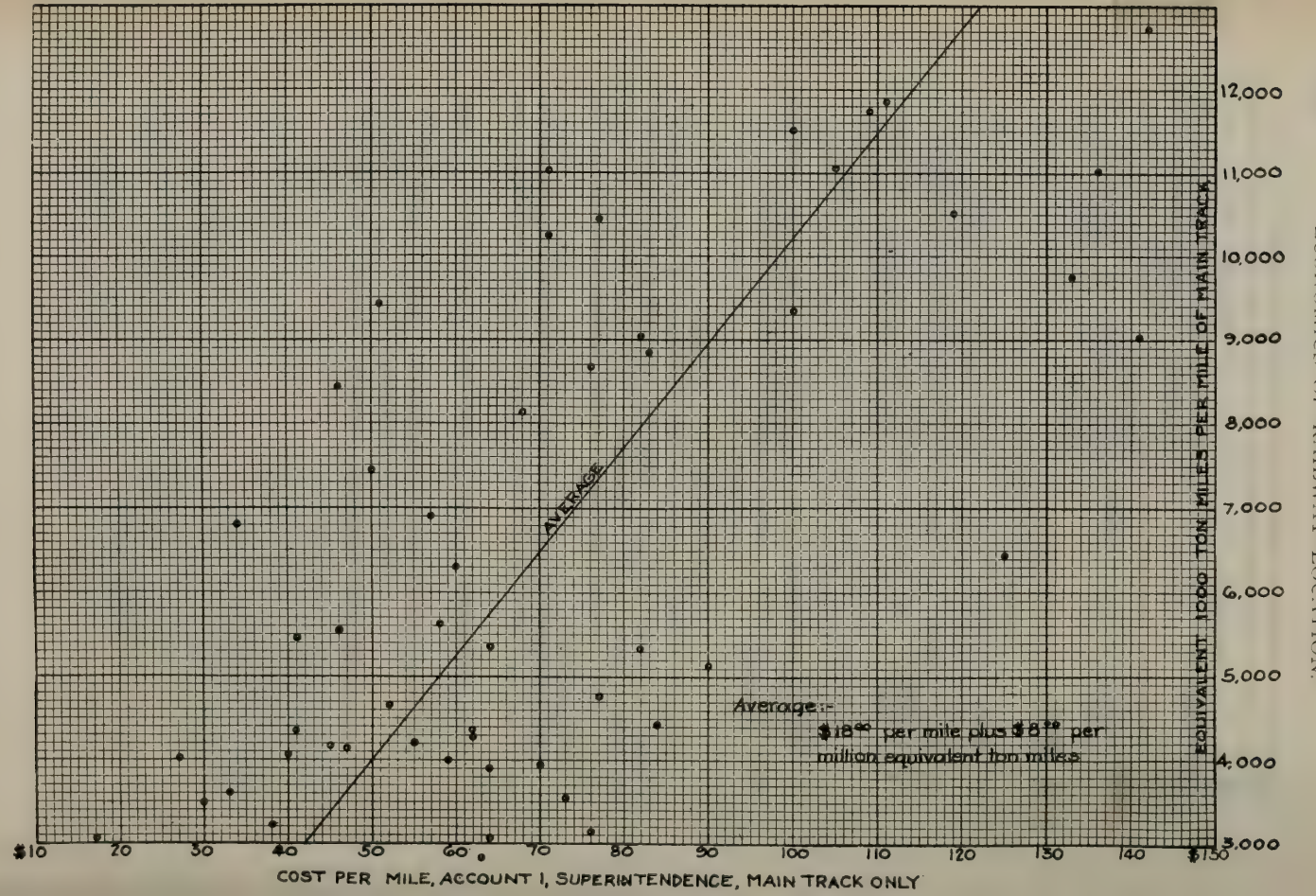
That Conclusions 3 and 7 be eliminated and the matter under subhead 1 on page 618 of this report be substituted; also the table on page 615.

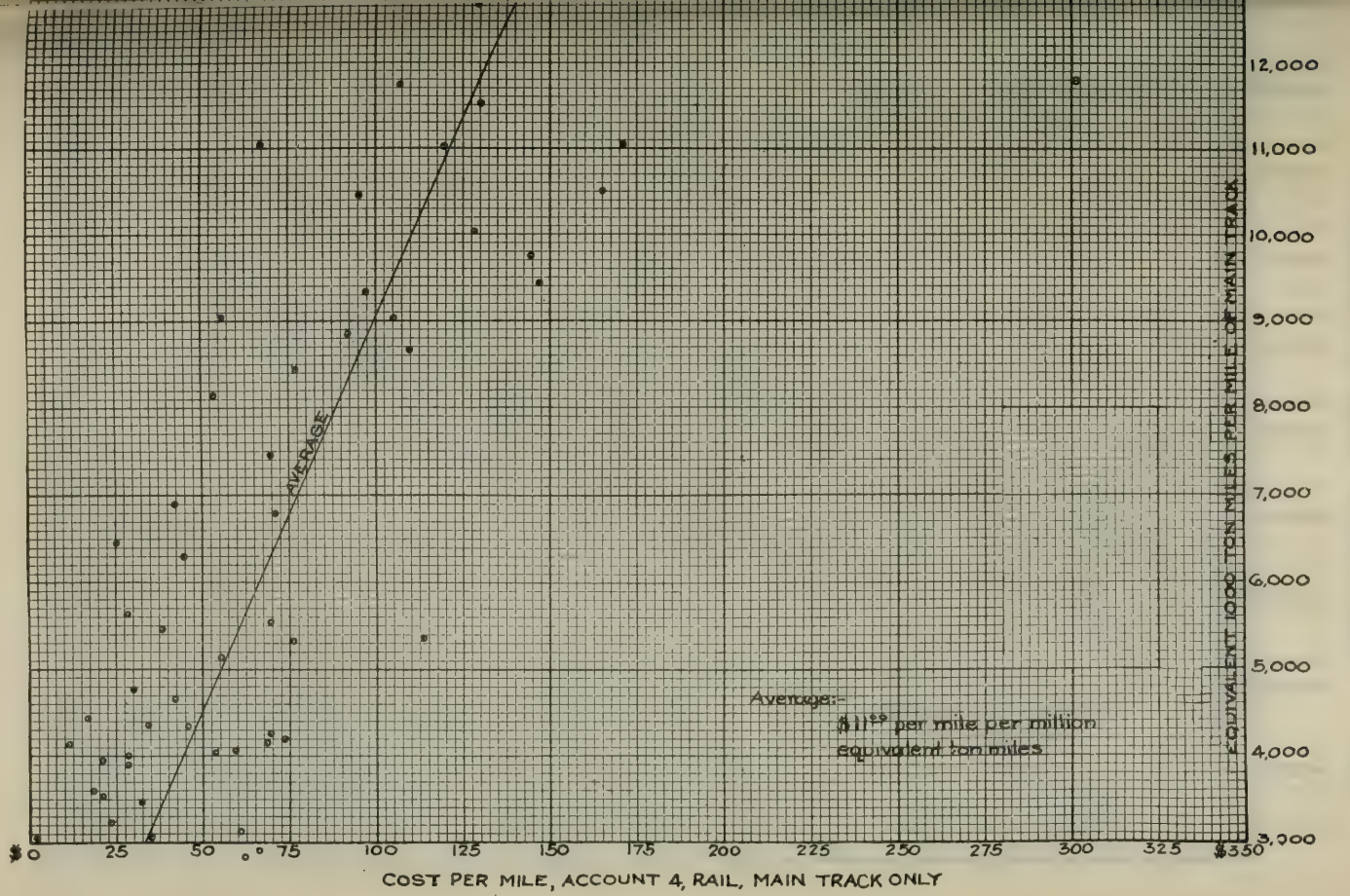
That for Conclusion 4 there be substituted Conclusions 1-4 on pages 620 and 621.

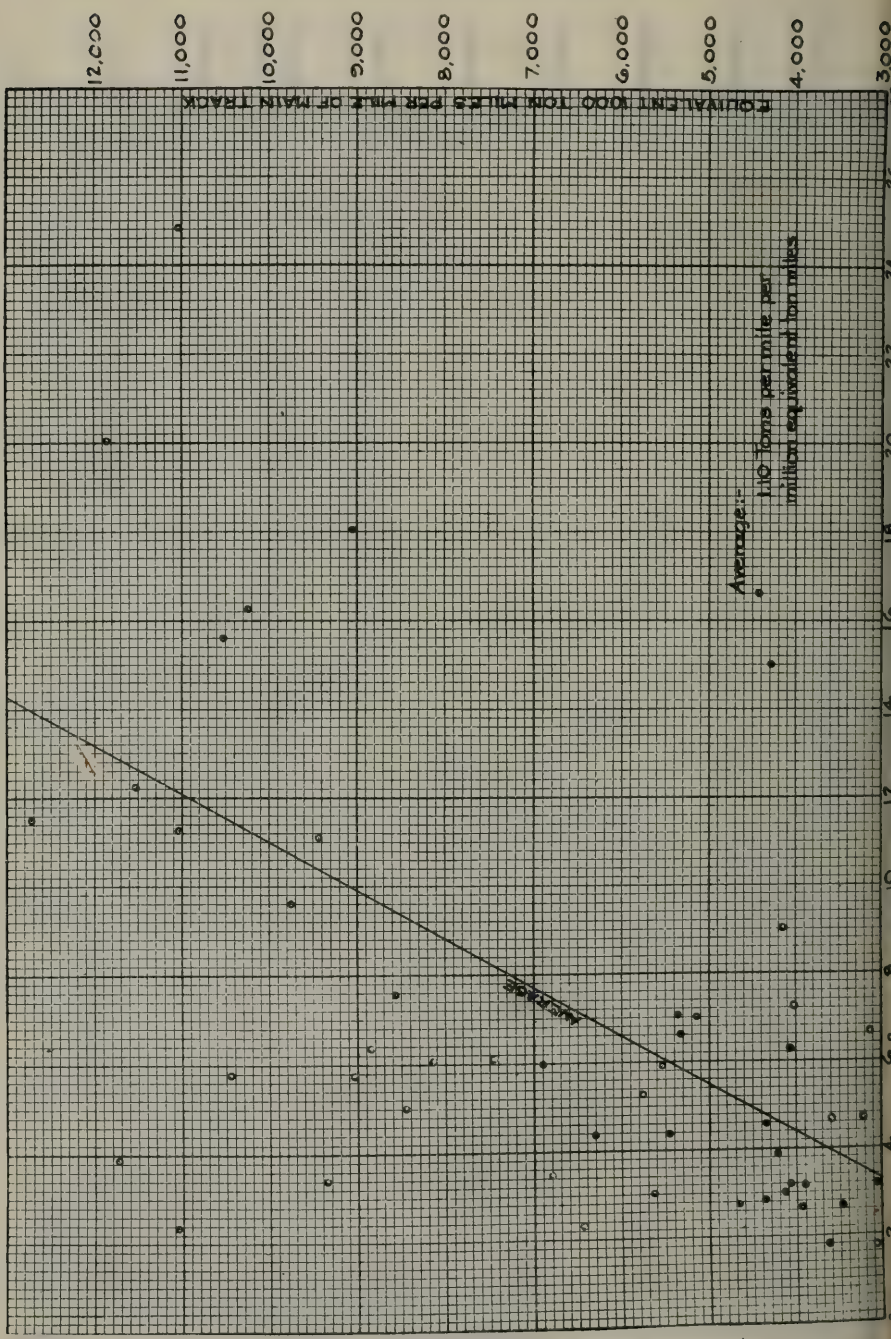
That Conclusions 8 and 9 be renumbered 7 and 8, respectively.

Respectfully submitted,

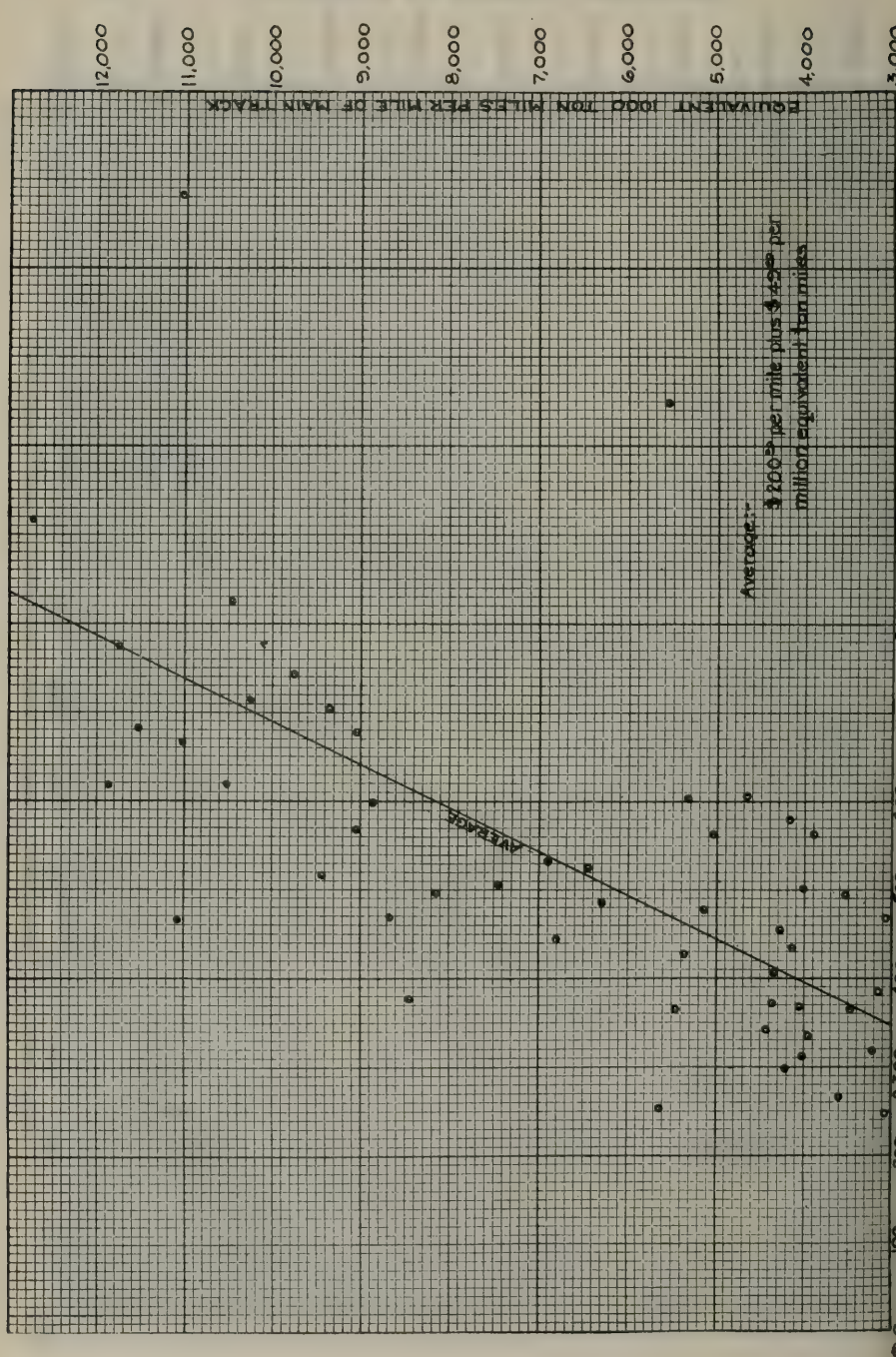
COMMITTEE ON ECONOMICS OF RAILWAY LOCATION.

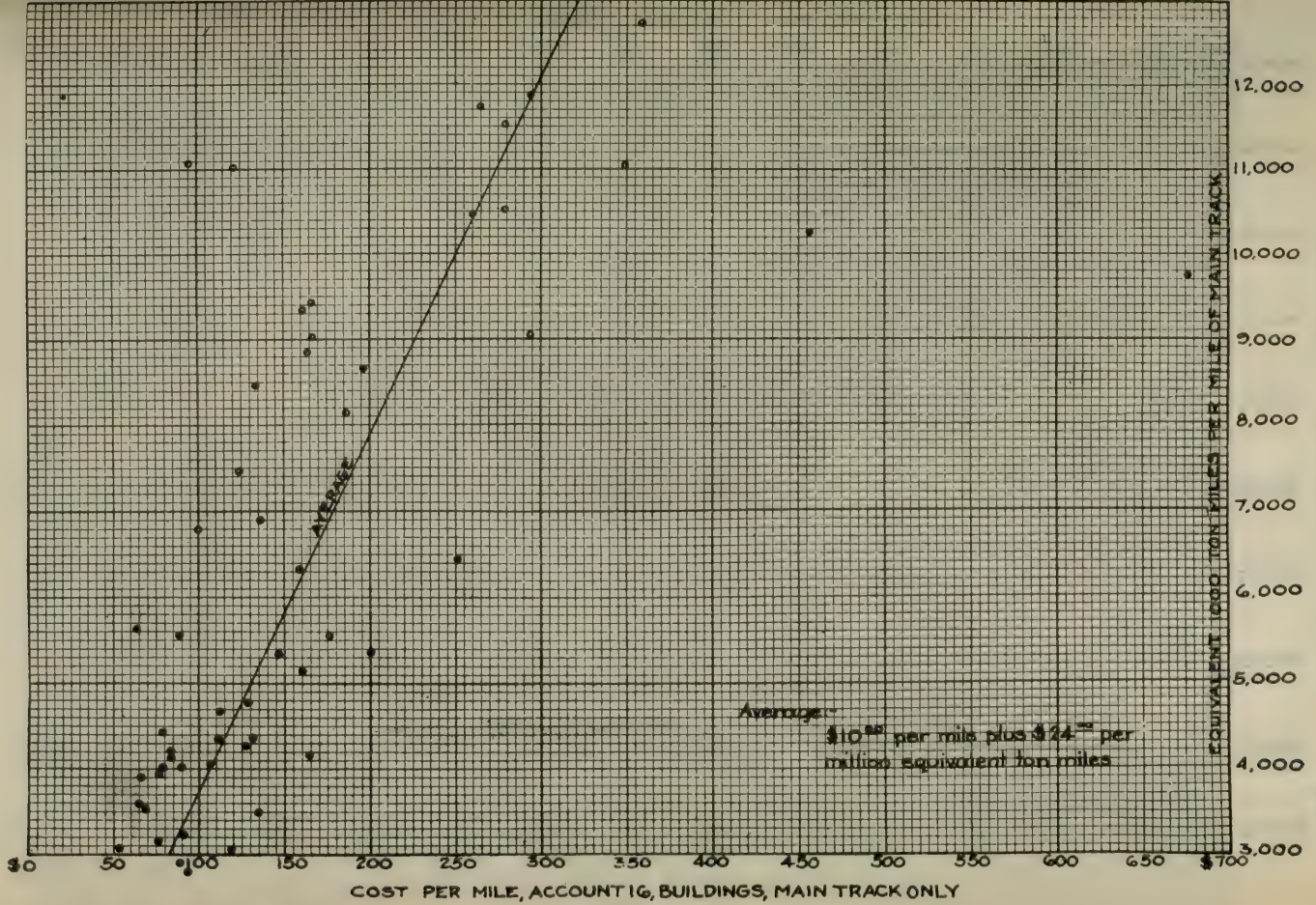

AVERAGE
Average:-
$18.00 per mile plus $8.20 per million equivalent ton miles
EQUIVALENT 1000 TON MILES PER MILE OF MAIN TRACK
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
$10
20
30
40
50
60
70
80
90
100
110
120
130
140
$150
COST PER MILE, ACCOUNT 1, SUPERINTENDENCE, MAIN TRACK ONLY

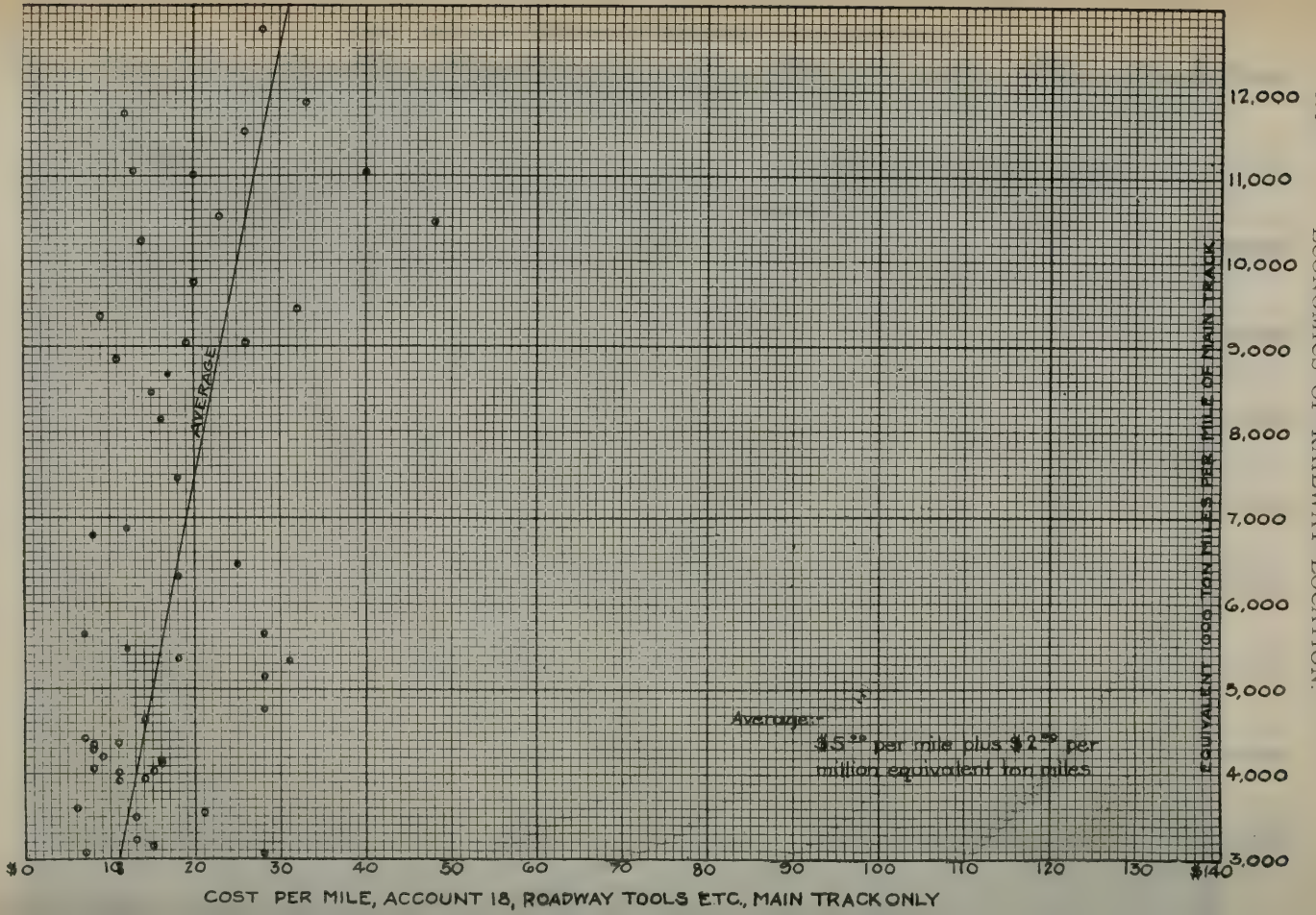

AVERAGE
Average:-
$11.09 per mile per million equivalent ton miles
EQUIVALENT 1000 TON MILES PER MILE OF MAIN TRACK
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
$0
25
50
75
100
125
150
175
200
225
250
275
300
325
$350
COST PER MILE, ACCOUNT 4, RAIL, MAIN TRACK ONLY


12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
EQUIVALENT 1000 TON MILES PER UNIT OF MAIN TRACK
Average:-
1.10 tons per mile per million equivalent ton miles
28
26
24
22
20
18
16
14
12
10
8
6
4
2

EQUIVALENT 1000 TON MILES PER MILE OF MAIN TRACK
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
Average:
$10.29 per mile per million equivalent ton miles
ALIGNMENT
$0
15
30
45
60
75
90
105
120
135
150
165
180
195
$210
COST PER MILE, ACCOUNT 5, OTHER TRACK MATERIAL, MAIN TRACK ONLY


EQUIVALENT 1000 TON MILES PER MILE OF MAIN TRACK
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
$1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
$
AVERAGE
Average:-
$1200 per mile plus $ 4.25 per million equivalent ton miles


AVERAGE
Average:-
$10.88 per mile plus $24.33 per million equivalent ton miles
EQUIVALENT 1000 TON MILES PER MILE OF MAIN TRACK
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
$0
50
100
150
200
250
300
350
400
450
500
550
600
650
$700
COST PER MILE, ACCOUNT 16, BUILDINGS, MAIN TRACK ONLY


AVERAGE
Average:-
$5.00 per mile plus $2.50 per million equivalent ton miles
EQUIVALENT GROSS TON MILES PER MILE OF MAIN TRACK
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
$0
10
20
30
40
50
60
70
80
90
100
110
120
130
$140
COST PER MILE, ACCOUNT 18, ROADWAY TOOLS ETC., MAIN TRACK ONLY

Appendix A.

RATIO OF LOCOMOTIVE EQUIVALENT TON MILEAGE TO TOTAL.

The accompanying table shows the per cent. of Equivalent Ton Mileage that the locomotive bears to the total equivalent ton mileage of its class of traffic for the roads given in the table in the body of the report. Owing to the fact that both tables were made on the average weight of locomotives of the road, passenger and freight engines considered the same, the percentage shown for freight locomotives is probably lower than it should be and the percentage for passenger service higher since the average freight locomotive weighs more than the passenger types.

PER CENT. LOCOMOTIVE EQUIVALENT TON MILEAGE BEARS TO TOTAL EQUIVALENT TON MILEAGE OF ITS CLASS OF TRAFFIC.

ROAD	Frt.	Pass.	ROAD	Frt.	Pass.
Penn. R. R	20	55	L. & N. R. R	27	50
D. L. & W. R. R	23	49	So. Pac., and G. H. & S. A	23	49
Penn. Co	21	51	A. T. & S. F. Ry	28	53
P. & L. E. R. R	11	57	Un. Pac., O.S.L., O.W.R.&N.	24	51
N. Y. C. & St. L. R. R.	19	39	N. C. & St. L. Ry	29	47
P. & R. Ry	21	57	C. G. W. R. R	24	54
Vandalia R. R.	24	50	C. B. & Q. R. R	22	48
L. S. & M. S. Ry	20	52	C. & N.-W. Ry	26	51
N. Y. C. & H. R. R. R.	24	53	C. R. I. & P. Ry	27	52
C. R. R. of N. J	28	58	Can. Pac. Ry	25	45
Northern Cen. Ry	21	54	M. K. & T. Ry. (Incl. Texas).	26	48
N. & W. Ry	24	55	Southern Ry	28	53
C. C. C. & St. L	23	62	C. St. P. M. & O. Ry	27	44
Erie R. R	22	51	C. M. & St. P. Ry	26	47
Lehigh Valley R. R	21	54	Nor. Pac. Ry	24	53
B. & O. R. R	26	57	Great Nor. Ry	21	48
P. B. & W. R. R	24	52	St. L. & S. F. R. R	29	53
D. & H. Co	28	60	Pere Marquette R. R	23	53
C. C. C. & St. L. Ry	22	54	Texas & Pac. Ry	24	48
C. & O. Ry	18	55	Mo. Pac., St. L. I. M.& S.Ry	26	54
Wabash R. R	22	51	D. & R. G. R. R	34	50
C. & A. R. R	23	54	Y. & M. V. R. R	17	40
Ills. Cen. R. R	22	49	Seaboard Air Line Ry	28	48
Long Island R. R	40	41	Atlantic Coast Line R. R.	24	47
D. M. & N. Ry	15	61	M. St. P. & S. Ste. M. Ry	23	49
C. & E. I. R. R	19	63	Cen. of Georgia Ry	24	41
Mobile & Ohio R. R	25	50			

This table is given as information to show the approximate amount of damage done by the locomotive for each class of traffic, on the basis of one ton of locomotive doing double the damage of one ton of the balance of its train. The question of the exact ratio of damage is an intricate one and would require more data than the committee has at present. There is no strong probability that the average axle load of

locomotive and tender will reach the exceptionally heavy loading given for the extra heavy Mikado type in the report for many years, even if it ever does, and the modern consolidation will, in the majority of cases, represent the average to be considered in estimating values of locations.

It is interesting to note that by the proposed method of equivalent ton miles the passenger locomotive does as much damage as the balance of its train, while the freight locomotive does about one-third as much as the balance of its train on the average. The two extremes of freight service are represented by the Pittsburgh & Lake Erie Railroad, which with its low grades averages about 16.5 tons of cars and contents to each ton of locomotive, and the Denver & Rio Grande Railroad with its very heavy mountain gradients averages about 3.9 tons cars and contents per ton of locomotive. The extremes in passenger service are the New York, Chicago & St. Louis Railroad, averaging 3.15 tons passenger cars to one ton of locomotive, and the Chicago & Eastern Illinois Railroad, averaging 1.88 tons per locomotive ton.

In former practice the locomotive has been frequently considered as affecting track in a fixed ratio to the balance of its train, but examples above will show the inconsistency of using such methods. It is to be hoped that data will become available to fix the factor with more certainty than the one assumed in this report.

Appendix B.

DYNAMOMETER TESTS—BALTIMORE & OHIO RAILROAD.

APPLICATION TO TONNAGE RATING.

By R. N. Begien,

Assistant General Superintendent, Main Line System, Baltimore & Ohio Railroad.

DYNAMOMETER RUNS.

Many miles have been run with dynamometer cars, but few real results have been obtained which give reliable data concerning train resistance.

The number of formulæ in use only serve to inspire a serious doubt as to the accuracy of any of them.

What, then, is the reason for all this difference of opinion?

It is true that some dynamometer charts have not been properly studied, but there are also many unknown factors which make the interpretation of the charts difficult.

Facilities for making these tests properly are rarely had. It is an expensive matter to make the tests and an equally expensive one to analyze the charts.

The results obtained seldom agree with the preconceived notions of those who use them, causing modifications and amplifications of a more or less "practical" nature. The verdict is, generally, that the only way to make a rating is to try different loadings until the correct one is found, and then use it.

This method would be all right if the loading adopted as the result of such trials was a proper one for all conditions of cars and condition of track and weather. There is also a difference of opinion as to what constitutes a correct rating.

It is a mistake to suppose that proper ratings depend entirely on the power of the locomotive and the grade; yet *the ideal condition is realized when such facilities for handling trains are supplied that those two factors control the rating.*

The tests described have demonstrated that with the wide variation of working conditions on a railroad, there is no such thing as an absolute value to train resistance.

It is, however, possible to establish a practical base which is on the safe side and will give good working results.

Since the object of tonnage rating is to establish a standard by which performance may be measured, it is better to predetermine that standard than to allow each one to make his own.

The inevitable result of the establishment of standards is good, since uniformity of performance approximating a proper standard always yields a higher average than a mixture of high and low grade performance. In other words, good results may be obtained by doing well all the time.

STUDY OF DYNAMOMETER RECORDS—TESTS, APPARATUS, CHARTS, RECORDS.

TESTS—OCTOBER, 1910, TO JANUARY, 1911.

During the months of October, November and December, 1910, and January, 1911, dynamometer tests were made on the Baltimore & Ohio Railroad, with trains made up as naturally resulted from traffic conditions. The tests extended over all the main lines and more important branches of the road, thus embracing a wide variety of conditions.

The profiles of many of the divisions were specially run for these tests.

PURPOSE OF TESTS.

The purpose of the tests was to determine, from an analysis of the records, made under service conditions, whether any definite formula for train resistance could be developed which would be of general application for purposes of equating train resistance and tractive power of engines.

DYNAMOMETER AND RECORDING APPARATUS.

The dynamometer used was of the direct pull oil cylinder type with piston rod connected to the drawbar of the car. The recording apparatus of the car was described in the Railway Age of April 13, 1906, page 655.

GRAPHICAL CHARTS AND SUPPLEMENTARY RECORDS MADE.

Graphical charts were made by the recording apparatus showing continuous records of the following items of information:

(a) Location of the test car upon the road.
(b) Time elapsed since beginning of test (½ min. intervals).
(c) Mile posts.
(d) Speed in miles per hour.
(e) Drawbar pull of locomotive.
(f) Injector in use or shut-off.
(g) Coal fired (number of scoops).
(h) Boiler pressure.
(i) Train line (air) pressure.

Notations of temperature and weather conditions were made as often as change occurred. Data of train consist, weight and length were entered

on the charts. On the engine, "log books" were kept preserving tabulated records of

Position of reversing lever,
Position of throttle lever,
Use of injector,
Boiler pressure,
Scoops of coal fired,
Water consumed,

and other data relating to the tests.

METHOD OF CALCULATING RESULTS.

PURPOSE OF THE CALCULATION.

The purpose of the calculation was to determine the total frictional train resistance at intervals of one-half minute throughout each test run. To do this, it was necessary to calculate the resistances due to grade, curvature, and acceleration at each half-minute interval, and to subtract the sum of these resistances at each such point from the total drawbar pull developed by the engine at that point. The remainder, being the total frictional train resistance, was divided by the weight of the train in tons, thus obtaining the frictional train resistance in pounds per ton. This method gives the momentary values of "train resistance" at the points considered.

SCALE OF GRAPHICAL CHARTS.

The speed of the paper travel used on the recording machine throughout the tests was such as to make the graphical charts on a scale of three inches to the mile.

HALF-MINUTE POINTS ON CHARTS.

A distinctive mark on the time record line shown on the charts was made to indicate the expiration of each half-minute interval. The points so indicated will hereinafter be spoken of as "Half-minute Points."

It was necessary to determine for each half-minute point the speed of the train, the difference in feet of elevation between the rear of the tender and the rear of the caboose, and the degree of curvature of the section of track on which the train was located at that instant.

SPEED AT HALF-MINUTE POINTS.

To determine the speed at each half-minute point, the average speed during the half-minute interval preceding was added to the average speed during the half-minute interval succeeding and the sum having been divided by two, the result was considered as the speed at the point under consideration.

AVERAGE SPEED FOR HALF-MINUTE INTERVALS.

The average speed during each half-minute interval was determined as follows: Through each half-minute point a vertical line was drawn cutting the drawbar pull record line, the "Distance" record line and the "Location" record line.

MILEAGE FROM A KNOWN POINT.

Having selected on the chart some well-established "Location" point (such as a signal tower), it was given the mileage designation corresponding to its mileage on the track profile. The distance from this "Known Point" to each "Half-minute Interval" was scaled and the resulting mileage figure assigned.

HUNDRED-FOOT STATION.

The mileage of each half-minute point was then reduced to terms of "Hundred Foot Stations," corresponding to the "Stations" on the track profile by multiplying by 52.8.

FINAL CALCULATION FOR AVERAGE SPEED FOR HALF-MINUTE INTERVAL.

Finally, to determine the average speed during a given half-minute interval, the difference between the mileage figures corresponding to the two adjacent half-minute points between which the interval lay was taken and multiplied by 120. This speed was checked by scaling between the half-minute points with a 40 parts to the inch scale, reading one "mile per hour" for each 1/40 inch.

TABULATION OF THE CALCULATIONS.

The calculations were tabulated as indicated on the "Sample Sheet" attached. This tabulation shows columns headed, "Time," "Miles," "Stations," "Grade Factor," i. e., difference in feet of elevation between rear of tender and rear of caboose; "Speed," "Speed Difference," i. e., increase in speed during the half-minute interval; "Speed Force," i. e., pounds of available drawbar pull consumed in acceleration; "Grade Force," i. e., pounds of available drawbar pull consumed in overcoming the resistance due to grade and curvature; and "Speed Force plus Grade Force," i. e., the sum of the two items next preceding and the total amount to be subtracted from total drawbar pull, leaving as remainder total "Train Resistance."

The following is an explanation of the method of securing the data for filling in the calculation sheet.

ACCELERATION FOR HALF-MINUTE INTERVALS.

The "Speed Difference" was deduced from the "Speeds" by subtraction, and shows the average acceleration in miles per hour for half-minute intervals. A (+) sign indicates increasing acceleration, and a (—) sign indicates decreasing acceleration.

SAMPLE SHEET, SHOWING METHOD OF TABULATING THE CALCULATIONS.

Time hr.m.	Miles from Starting	100 ft. Station	Grade Factor	Speed	Sp. Dif.	Sp. Force	Gr. Force	Sp.+Gr. Force
12:03:00	4.920	259+80	+4.2	0.4*		+6550	+15600	+22150
				0.8†	+0.8			
:30	4.926	260+14	+4.1	1.2		+6550	+15250	+21800
				1.6	+0.8			
:04:00	4.939	260+80	+4.1	2.0		+6550	+15250	+21800
				2.4	+0.8			
:30	4.960	261+90	+4.2	2.8		+6550	+15600	+22150
				3.2	+1.0			
:05:00	4.905	263+00	+4.2	3.7		+8200	+15600	+23800
				4.2	+1.3			
:30	5.017	264+90	+4.2	4.85		+1065	+15600	+26250
				5.5	+1.0			
:06:00	5.063	267+25	+4.2	6.0		+8200	+15600	+23800
				6.5	+0.5			
:30	5.115	270+10	+4.2	6.75		+4100	+15600	+19700
				7.0	+0.2			
:07:00	5.174	273+20	+4.2	7.1		+1650	+15600	+17250
				7.2	+ .0			
:30	5.236	276+50	+4.2	7.2		+ 0	+15600	+15600
				7.2	+0.1			
:08:00	5.297	279+70	+4.2	7.25		+ 800	+15600	+16400
				7.3	+0.1			
:30	5.357	282+90	+4.2	7.35		+ 800	+15600	+16400
				7.4	+0.3			
:09:00	5.411	286+10	+4.2	7.55		+2450	+15600	+18050
				7.67	+0.3			
:30	5.475	289+50	+4.2	7.85		+2450	+15600	+18050
				8.0	+0.3			
:10:00	5.551	293+10	+4.2	8.15		+2450	+15600	+18050
				8.3	+0.3			
:30	5.623	296+90	+4.2	8.45		+2450	+15600	+18050
				8.6	+0.2			
:11:00	5.693	300+60	+4.2	8.7		+1650	+15600	+17250
				8.8	+0.2			
:30	5.767	304+50	+4.2	8.9		+1650	+15600	+17250
				9.0	+0.2			
:12:00	5.842	308+50	+4.2	9.1		+1650	+15600	+18050
				9.2	+0.3			
:30	5.916	312+40	+4.2	9.35		+2450	+15600	+18050

*Speed at time shown.

†Average speed between the previous time shown and the following time shown.

"SPEED FORCE" NEEDED TO OVERCOME RESISTANCE DUE TO ACCELERATION.

G. R. Henderson, in his *Locomotive Operation*, gives the force of acceleration or retardation as:

(1) $$Pt = C\frac{V_2^2 - V_1^2}{S}$$

Pt = energy in lbs. per ton.

C = constant.

V_1 = and V_2 = velocities considered in miles per hour.

S = distance in feet.

For a constant time interval of 30 seconds.

(2) $$S = \frac{5280}{120}\frac{V_2 + V_1}{2} = 22\,(V_2 + V_1) = \text{feet per half minute.}$$

Substituting (2) in (1).

$$Pt = \frac{C\,(V_2^2 - V_1^2)}{22(V_2 + V_1)} = \frac{C}{22}\,(V_2 - V_1).$$

The revolving wheels tend to increase the effective inertia in a horizontal direction in a loaded car by 3 per cent., and in an empty car by 8 per cent.

Applying these percentages to 66.76 (page 3, Henderson) gives:

$C = 1.03 \times 66.76 = 68.76$ for loaded cars.

$C = 1.03 \times 66.76 = 68.65$ for loaded cars.

Then $Pt = \frac{68.65}{22}\,(V_2 - V_1) = 3.12\,(V_2 - V_1)$ for loaded cars.

$= \frac{72.1}{22}\,(V_2 - V_1) = 3.28\,(V_2 - V_1)$ for empty cars.

$= 3.20\,(V_2 - V_1)$ for partly loaded.

The total force of acceleration for a train, for interval of 30 seconds, is:

$$P = KT\,(V_2 - V_1).$$

when P = total force of acceleration (+ when speed is increasing, and — when decreasing).

K = constant varying from 3.12 to 3.28 as above.

T = actual tonnage of train behind tender.

$V_2 - V_1$ = change of velocity in miles per hour.

$V_2 - V_1$ was taken to the nearest tenth mile and tables prepared for each train consist to show P for any change of velocity appearing in the speed difference column.

GRADE FACTOR.

The grade factor was scaled from the profile and shows the difference in elevation in feet between the rear of the tender and the rear of the caboose at the half-minute point, the length of the train having been computed from the train consist, and laid down to scale on the track profile, according to the position of the head end of train, shown in the "Station" column. A (+) "Grade Factor" indicates an ascending grade, and a (—) "Grade Factor" indicates a descending grade in the direction in which the train is moving.

CURVE RESISTANCE.

Curvature was allowed for in the "Grade Factor" by adding a (+) quantity to the difference in elevation between the ends of the train, at the rate of .04 ft. for each degree of central angle occupied by the train for curves of over 1,000 ft. in length, and shorter curves when the tangent track between them was so small that the train may be taken to be entirely on curve. For curves less than 1,000 ft. in length, the compensation was taken at .03 ft. per degree of central angle.

"GRADE FORCE" NEEDED TO OVERCOME RESISTANCE DUE TO GRADE.

The force consumed in overcoming the resistance due to grade and curvature is:

$$F^1 = \frac{G \times 20}{L}.$$

F = force in lbs. per ton (+ when grade is ascending, and — when descending).

G = "Grade Factor" in feet.

L = length of train behind tender expressed in "Stations" (units of 100 feet).

$F^1 = T \frac{G \times 20}{L}$ = Total "Grade Force" for train of (T) tons (L) 100-ft. stations in length.

$T \frac{20}{L}$ is a constant for each train consist and "F" was tabulated for different values of "G" to tenths of a foot.

TRAIN RESISTANCE.

"Speed Force + Grade Force" at each "Half-minute Point" was subtracted from the drawbar pull shown on the chart at that point leaving as remainder the total Train Resistance, which divided by the total tonnage of the train gave the momentary resistance in pounds per ton at that point.

FINAL RECORD TRAIN RESISTANCE READINGS.

Record books were used to preserve a tabulated record of the half-minute readings for each run, classifying the readings by speed ranges (1-5), (5-10), (10-15), (15-20), (20-30), (30-40), (40-50) miles per hour, and by temperature ranges (20 deg. to 35 deg.), (35 deg. up). Chosen ranges of car weight—(below 20 tons), (20 tons to 30 tons), (30 tons to 40 tons), (40 tons to 50 tons), (50 tons to 60 tons), (60 tons to 70 tons), (over 70 tons).

Sample page of Record Book used to preserve a tabulated record of the half-minute readings for each run is attached.

PLOTTING CHART FOR EACH RUN.

A chart was made for each run—plotting "Resistance" and "Time" vertically against "Distance from Start" horizontally. The legend shows "Average Car Weight," "Temperature Ranges" and "Speed Ranges," and for each point plotted a note is made of the number of half-minute readings averaged to give the value plotted. Each value plotted is the average of ten or less half-minute readings.

PLOTTING COMBINED "STOP CHARTS."

From the "Run Charts" were selected all "Stops" of sufficient length to cause an increase of 3 lbs. per ton in "Resistance." (Increase in "Re-

sistance" caused by a stop was determined by averaging all half-minute readings for fifteen minutes before the stop and subtracting from the average of all half-minute readings for fifteen minutes after the stop). These selected "Stops" were plotted on the charts as "Zero Distance." "Resistance" was plotted vertically against "Distance from Stop" horizontally. For each "R" value plotted, the number of half-minute readings averaged to secure the value was indicated.

SAMPLE PAGE OF RECORD BOOK USED TO PRESERVE A TABULATED RECORD OF HALF-MINUTE READINGS FOR EACH RUN.

Newark Division. Chicago Junction to Newark.
1st No. 40. Engine 2664. Slow Freight.
December 2d, 1910.

Speed 20-25 m.p.h. Temperature 20°-30°. Avg. Car Wt., 18.6 tons.

Time	Time Since First Start	Miles from Start	Speed	Total Resist.	Resist. Lbs. Per Ton	Average Resist. Lbs. Per Ton
5:37:30	7:33:30	....	26.0	7000	8.02	.....
5:38	7:34	....	24.3	7000	8.02	.....
5:38:30	7:34:30	....	22.8	6500	7.45	.....
5:39	7:35	....	21.6	6500	7.45	(7.79)*
5:39:30	7:35:30	72.8	20.3	7000	8.02	38.96
5:59:30	7:55:30	....	24.7	7000	8.02	.....
6:0	7:56	....	24.7	6000	6.87	.....
6:00:30	7:56:30	....	24.8	7500	8.59	.....
6:01	7:57	....	24.2	7000	8.02	.....
6:01:30	7:57:30	....	23.1	7000	8.02	.....
6:02	7:58	....	22.4	6000	6.87	.....
6:02:30	7:58:30	....	22.4	7000	8.02	.....
6:03	7:59	....	22.4	7500	8.59	.....
6:30:30	7:59:30	....	21.8	6500	7.45	.....
6:04	8:00	....	21.8	4000	4.58	(7.39)*
6:04:30	8:00:30	80.1	22.4	5500	6.30	81.33
6:05	8:01	....	22.7	7000	8.02	.....
6:05:30	8:01:30	....	22.7	7000	8.02	.....
6:06	8:02	....	22.7	6000	6.87	.....
6:06:30	8:02:30	....	22.4	6000	6.87	.....
6:07	8:03	....	22.1	6000	6.87	.....
6:07:30	8:03:30	....	22.3	6000	6.87	.....
6:08	8:04	....	22.7	6500	7.45	.....
6:08:30	8:04:30	....	22.7	8000	9.17	.....
6:09	8:05	....	22.4	7000	8.02	.....
6:09:30	8:05:30	....	22.5	5500	6.30	(7.57)*
6:10	8:06	82.1	21.7	8000	9.17	83.36
6:15:30	8:11:30	....	20.3	8000	9.17	.....
6:16	8:12	....	21.9	7000	8.02	.....
6:16:30	8:12:30	....	23.5	9000	10.31	.....
6:17	8:13	....	24.7	7000	8.02	(8.82)*
6:17:30	8:13:30	84.4	25.0	7500	8.59	44.11

*Average values of resistance in pounds per ton used as plotting points on chart for the run.

FINAL CHARTS.

The "Final Charts" were obtained by classifying the "Stop Charts" by "Average Car Weight" and "Temperature Range" groups. The points on charts which could be so classified into one group were replotted into a series of charts varying from each other only in the "Speed Range" covered by each. A curve was then drawn on each chart so classified

and replotted, which indicated the "Resistance" value for that particular "Average Car Weight," "Temperature Range" and "Speed Range."

"Final Charts" from fourteen test runs have been worked up according to the preceding outline. These test runs have been grouped into three sets as follows:

Group No. 1.

(Temperature Range, 20 to 35 deg.)
(Average Car Weight, 30 to 46 tons.)

	Temperature.	Average Car Weight.	Total Tons.
Run No. 1	32-35 deg.	46 tons	1,693
Run No. 2	33-35 deg.	35.3 tons	954
Run No. 3	29-35 deg.	30.1 tons	1,084
Run No. 4	22-35 deg.	39.0 tons	1,246
Run No. 5	23-35 deg.	33.5 tons	1,071
Run No. 6	31-35 deg.	37.1 tons	1,225
Run No. 7	27-35 deg.	38.6 tons	1,159

Group No. 2.

(Average Car Weight, 10 to 30 tons.)
(Temperature Range, 20 to 35 deg.)

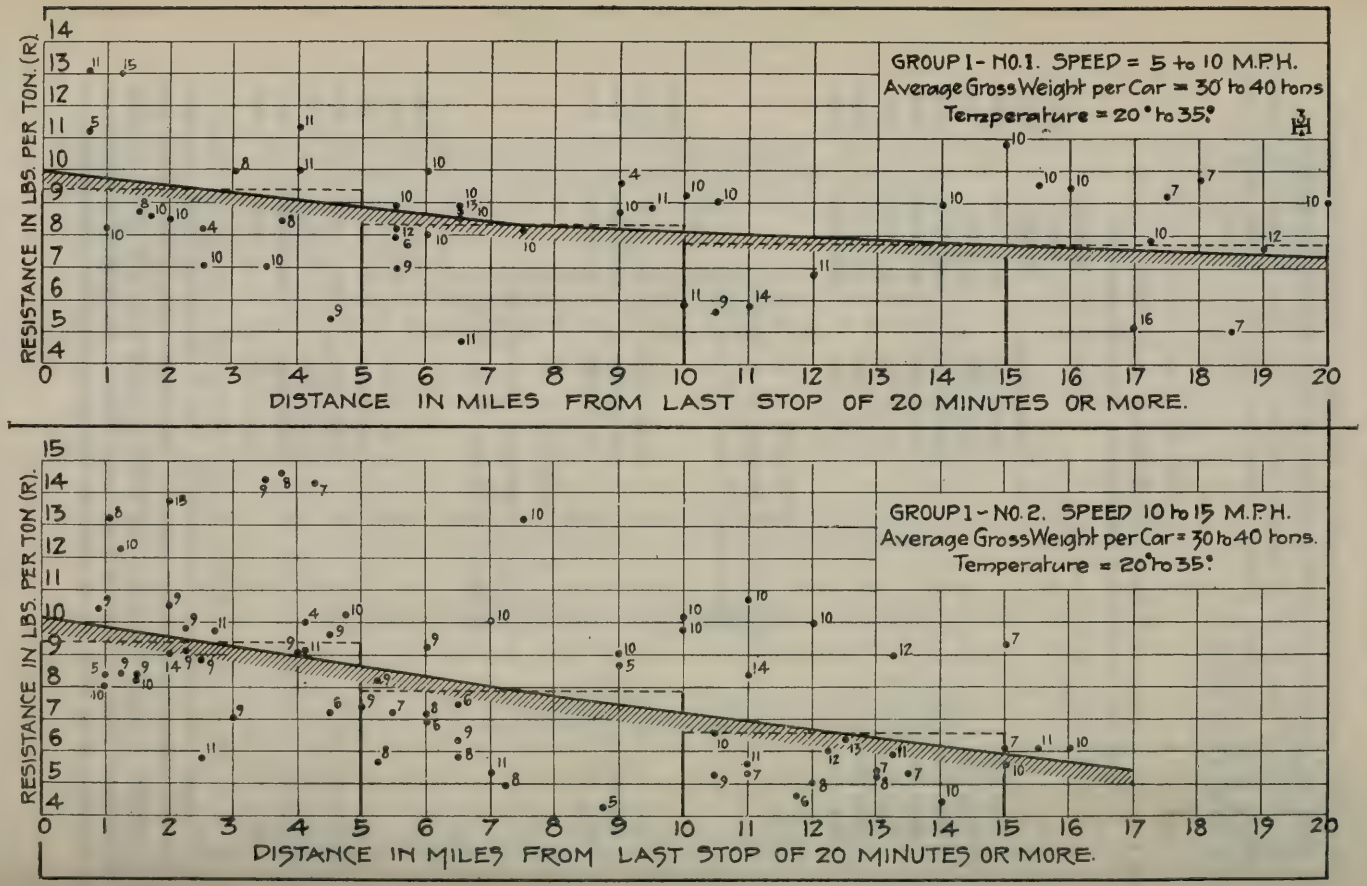
	Temperature.	Average Car Weight.	Total Tons.
Run No. 8	26-35 deg.	18.6 tons	874
Run No. 9	27-35 deg.	24.7 tons	839

Group No. 3.

(Average Car Weight, 30 to 50 tons.)
(Temperature Range, 35 to 60 deg.)

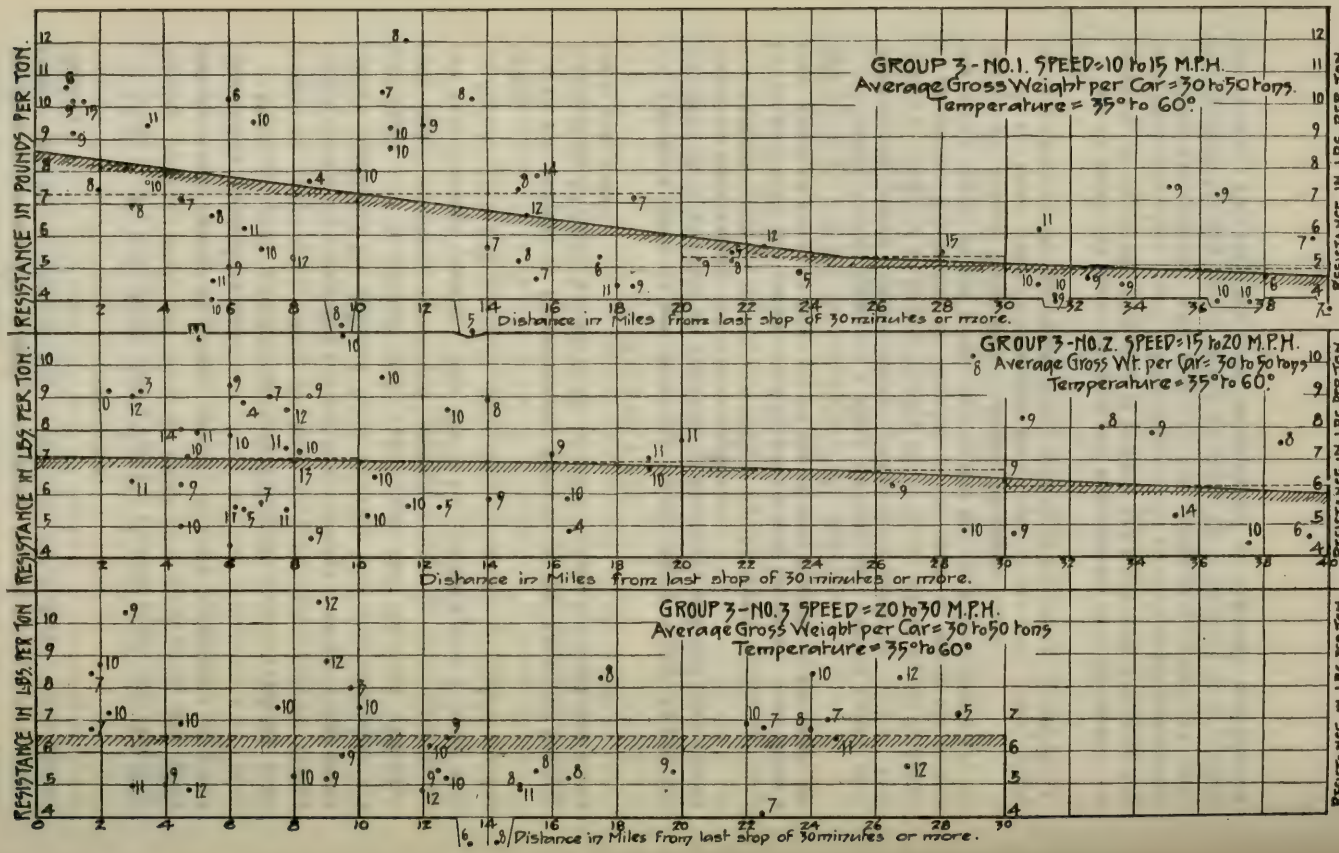
	Temperature.	Average Car Weight.	Total Tons.
Run No. 10	50-60 deg.	27.6 tons	382
Run No. 11	36-40 deg.	50.7 tons	1,370
Run No. 12	35-38 deg.	35.6 tons	1,244
Run No. 13	48-56 deg.	35.2 tons	914
Run No. 14	35-47 deg.	34.6 tons	1,108

It will be observed that in each of the three groups the range of average car weight, and in Group No. 3 the Temperature Range, is greater than contemplated in the outline. This modification of the outline was adopted in order to get as many points as possible in each set, from which to draw curves, it having been found that if the original outline were strictly adhered to there would not be enough points in each group to


GROUP 1 - NO. 1. SPEED = 5 to 10 M.P.H.
Average Gross Weight per Car = 30 to 40 tons
Temperature = 20° to 35°.
RESISTANCE IN LBS. PER TON. (R).
DISTANCE IN MILES FROM LAST STOP OF 20 MINUTES OR MORE.
GROUP 1 - NO. 2. SPEED 10 to 15 M.P.H.
Average Gross Weight per Car = 30 to 40 tons.
Temperature = 20° to 35°.
RESISTANCE IN LBS. PER TON (R).
DISTANCE IN MILES FROM LAST STOP OF 20 MINUTES OR MORE.

GROUP I: NO.3. SPEED = 15 to 20 M.P.H.
Average Gross Weight per Car = 30 to 40 tons
Temperature = 20° to 35°
GROUP I:-NO.4.- SPEED = 20 to 30 M.P.H.
Average Gross Weight per Car = 30 to 40 tons
Temperature = 20° to 35°
GROUP I:-NO.5.- SPEED = 5 to 30 M.P.H.
Average Gross Weight per Car = 30 to 40 tons
Temperature = 20° to 35°
(AVERAGES FROM NO.1 to 4 INCLUSIVE)
Distance in Miles from last stop of 20 minutes or more.
RESISTANCE IN POUNDS PER TON
RESISTANCE IN LBS PER TON

GROUP 2-NO.1. SPEED 10 to 15 M.P.H.
Average Gross Weight per Car=18 to 25 tons.
Temperature = 20° to 35°.
RESISTANCE IN LBS. PER TON.
Distance in Miles from last stop of 20 minutes or more.
GROUP 2 - NO.2. SPEED 15 to 20 M.P.H.
Average Gross Weight per Car=18 to 25 tons
Temperature = 20° to 35°
RESISTANCE IN LBS. PER TON.
Distance in Miles from last stop of 20 minutes or more.
GROUP 2-NO.3.- SPEED= 20 to 30 M.P.H.
Average Gross Weight per Car=18 to 25 tons
Temperature = 20 to 35°.
RESISTANCE IN LBS. PER TON.
Distance in Miles from last stop of 20 minutes or more.


GROUP 3 - NO. 1. SPEED = 10 to 15 M.P.H.
Average Gross Weight per Car = 30 to 50 tons.
Temperature = 35° to 60°.
RESISTANCE IN POUNDS PER TON.
RESISTANCE IN LBS. PER TON.
Distance in Miles from last stop of 30 minutes or more.
GROUP 3 - NO. 2. SPEED = 15 to 20 M.P.H.
Average Gross Wt. per Car = 30 to 50 tons
Temperature = 35° to 60°
RESISTANCE IN LBS. PER TON.
Distance in Miles from last stop of 30 minutes or more.
GROUP 3 - NO. 3 SPEED = 20 to 30 M.P.H.
Average Gross Weight per Car = 30 to 50 tons
Temperature = 35° to 60°
RESISTANCE IN LBS. PER TON.
Distance in Miles from last stop of 30 minutes or more.

indicate any definite results. Even under the modified plan the results are meager, Groups Nos. 2 and 3 not having enough points to give satisfactory indications. Group No. 1 is fairly satisfactory. (See plotted charts.)

CONCLUSIONS.

Study of the final charts shows that the plotting points fall at widely varying distances above and below the curve of average value, and, while the curve may readily be drawn, there is no close aggregation of points immediately along the curve.

Although other investigators have exhibited charts, resulting from studies of similar tests, which do show the points all practically falling on the curves, the conclusion reached in the present instance is that under service conditions the different items entering into train resistance are continually varying through such wide ranges that the total resistance, even under conditions considered constant, cannot be determined to be any very constant quantity. Nor can it be concluded that a curve may be drawn which will represent more than an average of widely varying values.

In the Manual of Recommended Practice of the American Railway Engineering Association is given the adopted formula for Train Resistance on a level grade

$$R = 2.2T + 122C.$$

The tests made do not show any results which would change that formula. It is probably as practical as necessary, and will give results which are close enough for service conditions.

Absolute accuracy is not essential, since the Train Resistance must be equated with the engine tractive power, and the latter must have a large factor of safety to make up for the varying capacity of the crew, the differences in fuel and the condition of the machine.

Attached to this paper is a sheet showing the tractive power of a Mikado type engine under different conditions of grade and speed. This engine is computed to have a tractive effort at full stroke at the cylinders of 50,300 lbs., but behind the drawbar at the speed at which the boilers can supply steam at full stroke only 47,805 lbs. on a level grade are effective, the balance being used to propel the engine iteslf.

At the same speed (5 miles per hour) on a .3 per cent. grade, 46,575 lbs. are effective, the difference being used to overcome the grade resistance.

At 10 miles per hour on a .3 per cent. grade, only 32,115 lbs. are effective, or 15,460 lbs. less than at 5 miles per hour. The difference has been used to produce speed. If the boiler could produce steam fast enough to supply the cylinders with steam at full stroke at 10 miles per hour, the available tractive power would be 46,575 lbs. (the same as at 5 miles per hour). This has not been accomplished as yet with coal-burning

engines, though oil burners can closely approximate such a performance.

It will, therefore, be seen that with this engine rated at 10 miles per hour there can be a margin of error of 15,460 lbs. of train resistance before the engine would stall on a .3 per cent. grade. If the train resistance were really higher than the formula gives, the effect would be a slowing of the train. As a matter of fact, the formula ordinarily gives results on the safe side.

There should always be a margin between the maximum tractive power of a locomotive and that used for ratings. Engines should not be rated for full stroking except at starting.

APPLICATION OF THE RESULTS TO THE DEVELOPMENT OF A FORMULA FOR "B" TEMPERATURES, SIMILAR TO THE FORMULA

$$R = 2.2T + 122C,$$

USED FOR "A" TEMPERATURES.

Formula for B Rating—Temperature, 20 to 35 deg.

Using charts in Groups Nos. 1 and 2, a formula for resistance in pounds per ton has been derived.

Averaging all readings shown at more than 10 miles from start, on charts in Group No. 2, Average Car Weight 21 tons, gives $R = 9.5$ lbs. per ton.

Averaging all readings shown at more than 10 miles from start, on charts in Group No. 1, average car weight 37 tons, gives $R = 6.7$ lbs. per ton.

Resistance formula $R = K\ (T) + K'\ (C)$, in which $T =$ Tons per Car and $C =$ Number Cars, K and K′ are constants.

Solve for value of K, as follows:

21-ton car: 21×9.5 lbs. $= 199.5 = K\ (21) + K'\ (1)$ (1)

37-ton car: 37×6.7 lbs. $= 247.9 = K\ (37) + K'\ (1)$ (2)

$$48.4 = K\ 16$$

$$K = 3.0.$$

Substitute K in (1) and solve for K′

$$199.5 = 3.0 \times 21 + K'$$

$$K' = 136.5.$$

Substitute values of K and K′ in Resistance formula,

$$R = 3.0\ T + 136.5\ C.$$

Comparison "B" temperature formula, $R = 3.0\ T + 136.5\ C$, with "A" temperature formula, $R = 2.2\ T + 122\ C$:

30-ton car:

(A) ..... $R = 2.2\ (30) + 122$

$= 188$ R per ton $= \frac{188}{30} = 6.25$ lbs. per ton.

(B) $R = 3.0\ (30) + 136.5$

$= 226.5$ R per ton $= \frac{226.5}{30} = 7.5$ lbs. per ton.

50-ton car:

(A) $R = 2.2\ (50) + 122$

$= 232$ R per ton $= \frac{232}{50} = 4.6$ lbs. per ton.

(B) $R = 3.0\ (50) + 136.5$

$= 286.5$ R per ton $= \frac{286.5}{50} = 5.7$ lbs. per ton.

70-ton car:

(A) $R = 2.2\ (70) + 122$

$= 276$ R per ton $= \frac{276}{70} = 3.9$ lbs. per ton.

(B) $R = 3.0\ (70) + 136.5$

$= 346.5$ R per ton $= \frac{346.5}{70} = 4.9$ lbs. per ton.

FORMULÆ FOR A, B, C AND D RATINGS.

Investigations made from data not as good as the preceding have enabled the completion of formulæ for other temperatures.

It is arbitrarily assumed that the ratings are called A, B, C and D, as follows:

A Rating for temperatures over 35 deg. Fahrenheit.

B Rating for temperatures between 20 deg. Fahrenheit and 35 deg. Fahrenheit.

C Rating for temperatures between 0 deg. Fahrenheit and 20 deg. Fahrenheit.

D Rating below zero Fahrenheit.

Without going into detail, the formulæ deduced (showing as well those previously described) are:

A Rating $R = 2.2\ T + 122$ C.
B Rating $R = 3.0\ T + 137$ C.
C Rating $R = 4.0\ T + 153$ C.
D Rating $R = 5.4\ T + 171$ C.

Ratings made on the basis of these formulæ have stood the test of practice. They should be used as a basis to work on and should be tempered by the judgment of the operating officer in charge on the ground.

Attached is a table showing the percentage of "A" rating represented by each one of the formulæ.

PERCENTAGE OF ADJUSTED RATINGS "B," "C" AND "D"
"A" RATING TAKEN AS 100%.

Per Cent. Grade	Adjustment	"B"	"C"	"D"
0.1	29	84	70	57
0.15	23	87	74	62
0.2	20	89	78	66
0.25	17	90	80	69
0.3	15	91	82	72
0.35	13	92	84	74
0.4	12	93	85	76
0.45	11	93	86	78
0.5	10	94	87	79
0.55	9	94	88	81
0.6	9	95	89	82
0.65	9	95	89	83
0.7	8	95	90	84
0.75	7	96	91	84
0.8	7	96	91	85
0.85	6	96	91	86
0.9	6	96	92	86
1.0	5	97	93	87
1.1	5	97	93	88
1.2	5	97	93	89
1.3	4	97	94	90
1.4	4	97	94	91
1.5	4	98	95	91
1.6	4	98	95	92
1.7	3	98	95	92
1.8	3	98	96	93
1.9	3	98	96	93
2.0	3	98	96	93
2.1	3	98	96	93
2.2	3	98	96	94
2.3	2	98	96	94
2.4	2	98	96	94
2.5	2	99	97	94
2.6	2	99	97	94
2.7	2	99	97	95
2.8	2	99	97	95
2.9	2	99	97	95
3.0	2	99	97	95

In practice the drop from "A" to "B" usually is made by giving trains "A" rating minus 50 tons or minus 100 tons, and gradually following the temperature rather than by changing suddenly.

It should be understood that decreased ratings are used for other conditions of weather than those caused by temperature, high wind being a frequent cause of reduction.

EFFECT OF TEMPERATURE.

When the frost comes in the fall, its effect begins to show up in increased transportation expense. The slow freights catch it first. For a while an effort is made to hold up the ratings, but the frost gets into the journals and the time of the run drags out until the items "Crews Relieved" and "Exceeded 16 Hours" cause a cut in the ratings.

Fast freights which make almost continuous runs without stops are not much affected by cold weather unless it is very severe. High winds, however, are very hard on both fast freights and passenger trains. The

combination of high winds and cold weather should be amply compensated by reduced ratings, as not only is the train resistance increased, but the loss of power on the engine affects its hauling capacity.

It is difficult to always "size up" the conditions a train is going to meet throughout its run so as to give it the proper tonnage. The following items should be considered:

(1) Trains leaving terminal in the afternoon will have the lower night temperatures to meet.
(2) Trains starting at night under severe cold may often pick up tonnage after the sun is up.
(3) Trains starting a run in the low altitudes will find colder weather in the mountains.
(4) Trains starting in the mountains may often take on tonnage in the low lands.
(5) Trains having many stops and starts will be affected by cold more than trains running continuously.
(6) Trains starting up-grade leaving terminal may haul larger ratings if helped leaving terminal for at least twenty minutes until the journals become warmed.
(7) Position of passing sidings plays an important part in rating trains in winter. If sidings are in such positions that a train starts out of siding on a down-grade or on a grade substantially less than the ruling grade, larger ratings may be handled than is the case where sidings are located on ruling grades.
(8) If trains can get out of terminals promptly and put in the time on the road instead of standing in yards, better rating may be handled than when a large part of the allowable time is consumed in doing nothing.

The effect of temperature on expense and on the revenue train load is as follows:

(1) Increased overtime.
(2) Increased yard expense.
(3) Increased enginehouse expense.
(4) Increased fuel—
    (a) For locomotives.
    (b) For heating.
(5) Increased damage to equipment on road.
(6) Increase account snow and ice.
(7) Increased other expense.
(8) Decreased train load.

As the revenue train load decreases, all of the expenses which vary with the train load increase. Since from 25 per cent. to 30 per cent. of all transportation expense varies directly with the train load (depending on the proportion of the road expense to all expense), it is evident that the effect of temperature is heavy

Of all the tonnage hauled on a railroad whose train load is above 300 revenue tons, only the slow freight maintains a train load constantly above the average.

Manifest trains rarely carry more than 50 cars, and do not average that much. The car load is light—five tons is fair—and 250 revenue tons is a high revenue train load.

Local freights make very low train load and haul freight at high expense for wages. There are often back hauls in local freight, which are a loss as far as revenue train load is concerned.

The effect of both local freights and fast freights, therefore, is to hold down the revenue train load.

Since temperature ratings affect slow freights principally, and fast freights and local freights to a lesser degree, it is evident that its effect on the revenue train load is quickly apparent.

In Middle Atlantic States the train load will decrease from 15 per cent. to 30 per cent. in winter, depending on conditions. When the proportion of heavy slow freight to the total business decreases, the drop in the train load is especially great.

On account of cold weather troubles at engine terminals and steam failures on the road, and for other reasons, locomotives make less mileage in winter than in summer. There is always trouble on long grades, where the fireman has to work continuously for more than an hour. Firemen do not like to perspire in the winter and they usually wear more clothes than necessary if they are exerting themselves. The engineer on his seat box is dressed for sitting still and not for helping out a fireman with a dying fire. So a drag engine with a heavy tonnage train often fails in the winter when it would be all right in summer.

The freezing of coal and ore in cars is a cause of great delay to the movement of cars, which often means light trains to get faster movement. The ordinary method of building fires under cars to thaw them out and pounding the hoppers with hammers results in increased expense apart from the delay to the cars. It takes men to build fires under cars and it costs money to furnish fuel to burn. It also takes extra force to beat hoppers.

If cold weather comes at a time when business is brisk, as in the winter of 1911-12, the expense in all departments is bound to be heavy.

It pays, therefore, to know something about effect of temperature on train haul.

APPLICATION OF THE FORMULÆ.

In practice there are two ways of allowing for variations of temperature.

(1) Keep the rating constant and vary the adjustment for each temperature.

(2) Keep the adjustment constant and vary the rating for each temperature.

They both amount to the same thing in determining the actual tons hauled, but in practice it is probably better to follow the second plan. By so doing, train crews readily see that a reduction in tonnage has been made, whereas, if the "Wheel Report" shows full tonnage and merely a change in the adjustment, they often think they are hauling "A" ratings in "C" weather.

CONCLUSIONS FROM DYNAMOMETER TESTS.

(1) Assuming—

A Rating is used at temperature over 35 deg. Fahrenheit,

B Rating is used at temperature between 20 deg. Fahrenheit and 35 deg. Fahrenheit,

C Rating is used at temperature between 0 deg. Fahrenheit and 20 deg. Fahrenheit,

D Rating is used at temperature below 0 deg. Fahrenheit,

the following formulæ are practical:

A Rating — $R = 2.2\ T + 122\ C$ (on level grade).

B Rating — $R = 3.0\ T + 137\ C$ (on level grade).

C Rating — $R = 4.0\ T + 153\ C$ (on level grade).

D Rating — $R = 5.4\ T + 171\ C$ (on level grade).

when R = total resistance of train in pounds.

T = tonnage of train in tons of 2,000 pounds.

C = the number of cars in the train.

(2) These formulæ should be used to represent the resistance of a train that has been in motion at least 15 minutes.

(3) It is practical to assume that the resistance will be constant up to 30 miles per hour.

(4) With reasonable ratings of the power, starting resistances are negligible in warm weather. The engine must have a greater margin in cold weather, and when starts have to be made on ruling grades (especially when they follow long stops) extra allowance should be made.

TONNAGE RATINGS.

Proper tonnage rating is that load which can be hauled by the engine under consideration over the road at an economical speed.

Owing to factors which are, in a measure, indeterminate, it is not an exact science. Strictly economical tonnage rating would be different for every train. This can readily be seen, since no two engines are in the same condition. In a like manner, some cars are in a better condition to be hauled than others. Road conditions differ on different parts of the same division and some men are better and more uniform performers than others. Perfect uniformity of mechanical and roadway conditions would result in large economies in the way of a decreased number of trains due to increased tonnage per train.

Where it is impossible to secure perfection, uniformity pays well, even if it costs money to get it.

OBJECT OF ADJUSTED TONNAGE RATING.

The object of adjusted tonnage rating is to give an engine the same amount of work to do regardless of whether a train is made up of heavy loads, light loads, empties, or any combination of them.

If all cars of the same weight had an equal resistance to traction, this would be absolutely possible. Different kinds of cars and varying conditions of track, weather and wind make it possible to only approximate the desired result. The formulæ shown in the conclusions do this. They have stood the test of practice.

DEFINITION OF ADJUSTMENT.

The adjustment is an arbitrary amount added to the weight of each car, whether loaded or empty, to equalize the pull on the engine under conditions of hauling loaded, empty or mixed trains.

USE OF ADJUSTMENTS.

Adjustments are functions of the rate of grade and the resistances of the train. Practically they vary only with the rate of grade.

Most operating divisions have broken profiles and different rates of grade, so that the ruling grade should be first determined. (The ruling grade is the grade which governs the train load.) The adjustment for that grade should be used. If train loads are adjusted correctly for limiting conditions, there will be no trouble with the other parts of the railroad as far as tractive power is concerned.

When helpers are in use, the adjustment should be for the single engine ruling grade. This procedure will establish an adjustment which will be too large for helper grades, but the error is on the safe side.

When possible, the grades should be established from recent profiles. If there are none, it is a good plan to run them.

THE VALUE OF KEEPING THE ROADWAY TO THE ORIGINAL PROFILE.

Railroad profiles change in the course of years. It is a well-known fact that fills settle, causing deep sags in the grade line. The raising of tracks through cuts is cheaper than ditching, but is responsible for summits in the cuts.

In the early days it was not as thoroughly realized as it is at the present time that maintenance of way was chiefly a matter of drainage. Shortage of money was also responsible, in a large measure, for narrow cuts which were difficult of drainage. In the effort to get away from this condition, and to secure a ditch, tracks were raised, causing steeper grades than were originally projected. Every cut being followed by a fill, the sequence of raised cuts and depressed fills has caused a wide variation from the original ruling grade.

On some lines, where the profile has been checked, it has been found that stretches of .3 per cent. grade have become 1 per cent. If places of this character occur near a point of heavy resistance, an immediate effect on the tonnage of a train is the result. When an engine is working with its bar well forward, with the fireman tired out, the fire dirty, and the steam pressure dropping, such places will cause the stalling of a train, and in a short time the frequent delays will result in decreased tonnage rating.

Raising tracks is not as economical as the section foreman and supervisor would lead us to believe. While better drainage is undoubtedly secured, it is generally better practice to clean the ballast, and widen cuts to secure a ditch, and to raise track only when it becomes necessary to put roadbed to a proper line and surface. On such occasions, grade stakes should be used to establish the grades.

On many railroads an effort has been made to place permanent monuments, so that the track could be kept at a constant elevation. The difficulty of maintaining monuments along a roadbed is well-known. They are not only likely to be a menace to the lives of the trainmen, but they are constantly settling, and being knocked by sectionmen, and occasionally by derailments. However, the importance of placing permanent monuments cannot be overestimated.

COMPENSATING OLD ROADBEDS.

In the early days of railroading, compensating for curvature was practically unknown. For many years it was probably unnecessary. Compensation for curvature is not vital to small trains running at speed. The resistance due to curvature is principally felt by heavy tonnage trains on ruling grades where the engine is rated at a high percentage of its cylinder tractive power. Various experiments have been made to determine how much reduction in grade would compensate for the added resistance of curvature. It has generally been the practice to compensate this at a stated amount, and, while this method is not as accurate as could be desired, it is very much better than no compensation at all. From considerable observation of the influence of curvature, together with the examination of numerous tests of its effect, it is felt that some rules can be laid down which will improve the present practice.

CONCLUSIONS.

1. Compensate .03 per degree:
   - (a) When the length of curve is less than half the length of the longest train.
   - (b) When a curve occurs within the first 20 ft. of rise of a grade.
   - (c) When curvature is in no sense limiting.

2. Compensate .035 per degree:

(a) When curves are between one-half and three-quarters as long as the longest train.

(b) When the curve occurs between 20 ft. and 40 ft. of rise from the bottom of the grade.

3. Compensate .04 per degree:

(a) Where the curve is habitually operated at low speed.

(b) Where the length of the curve is longer than three-quarters of the length of the longest train.

(c) Where super-elevation is excessive for freight trains.

(d) At all places where curvature is likely to be limiting.

4. Compensate .05 per degree wherever the loss of elevation can be spared.

An illustration will show what can be accomplished by compensation of curvature on old roadbeds:

Take a .5 per cent. grade five miles long, with an average curvature of 60 deg. per mile, without compensation. If the maximum curve is 6 deg. and the curve equal in length to the longest train, the curvature will have the same effect in limiting tonnage as a grade of .24 per cent. This, added to the .5 per cent. grade, would make a ruling grade of .74 per cent. The effect of the curvature on the five miles of grade would be 300 deg., which, at an average of .035 per degree, would amount to 10½ ft. If this 10½ ft. is added to the 132 ft. of rise in the five miles of grade, it will be equivalent to 142½ ft., or 28½ ft. to the mile, which is equal to a .54 per cent. grade. If this .54 per cent. compensated grade is laid so as to be superimposed immediately above the present roadbed, it will be found that by reballasting the track to permanent stakes on a .54 per cent. grade, a new ruling grade can be established, which will be .2 per cent. below the .74 per cent. equivalent to the .5 per cent. uncompensated grade. On a grade of this length, it will be possible to haul nearly 25 per cent. greater tonnage per train, thereby securing a very large economy in operation for a small expenditure of money.

COMPENSATION OF LOW GRADES.

The effect of curvature on low grades is generally greater than on heavy grades, provided the length of train is what would be justified by the low grade. In speaking of low grades, levels, .1 per cent., .2 per cent. and .3 per cent. grades are referred to.

On double track railroads, particular attention should be paid to curves, whether uphill, downhill, or level, at places where steam is being taken by the engine in moving in either direction. On virtual level grades each track should have its tangents slightly raised and its curves slightly sloping down hill, so that the pull by the engine may be uniform, and the resistance of the line constant. The value of keeping the line resistance constant becomes more important as the length of the train increases. One of the prime objections to hauling a long train is the danger of parting.

and in this danger curvature plays an important part. If the line is crooked, having many short curves, it is usual for the slack of the train to be constantly taken up and let out. If the engine runs out on a bit of straight track, when the rear of the train is bunched on the curves, it will accelerate faster than the other end of the train. Unless the engineer is watching, and using the brakes slightly, he may pull out a drawbar. If, on the other hand, the front end of the train is on a curve, and the rear end on straight track, the tendency is for the rear end to run in on the front end, and break a knuckle. It should not be supposed that it is impossible to have different classes of compensation on each track of a double track railroad.

SUPER-ELEVATION.

From a scientific standpoint (not always from a financial view), it is evident that a six-track railroad is the most desirable for a road that handles a three-speed service. This will give a passenger track, a fast freight track, and a slow freight track in each direction. Without attempting to discuss at this time what will be gained by the operation of a six-track railroad, it should be said that as many tracks as possible are justified if a standpoint of super-elevation alone is considered. Of course, it becomes necessary for a train to stop occasionally on a curve, and for that particular case the super-elevation is always wrong.

Inasmuch as no super-elevation at all is necessary at very low speeds, it may be eliminated entirely on tracks that are used exclusively for standing cars, and very low super-elevation, if any, should be used in yard tracks.

On a single-track railroad carrying more than one class of traffic, there are two ways to treat super-elevation:

(1) Make the freight tonnage rating as great as possible, and in accordance with the ruling grade. In this case, it will be necessary to elevate the curves for freight speed, and run the passenger trains slowly over ruling grades.

(2) Use a higher super-elevation for passenger speeds, and decrease the tonnage rating to make up for the increased resistance caused by the wheels of the freight trains binding against the lower rail.

Single-track railroads which are crooked can rarely haul as high a percentage of rating as double-track railroads, on account of the super-elevation being wrong. It is easy to see that every down-grade becomes an up-grade for movements in the opposite direction on a single-track road. Inasmuch as the movement downhill is likely to be faster than it is uphill, the super-elevation must be made for the downhill movement or introduce speed limits on downhill trains.

RESISTANCES, TRAIN, TOTAL, INCLUDING TRACK.

On single lines that are exclusively for freight, super elevation on ruling grades should be made for not over 15 miles per hour. It is less

expensive to slow down the descending movement than to reduce tonnage rating on account of excessive super-elevation.

This is especially true on curves of large central angle. As an example, a curve of 180 deg. is cited. Two engines (one helping) hauling 3,500 tons of coal ordinarily stalled on an 8-deg. 30-min. curve with 185 deg. central angle with 5½-in. elevation. The elevation was reduced to 3 in. and no difficulty was had. This curve was compensated .04 per degree and was on an .85 per cent. grade.

On many mountain roads a long train may be on seven or eight curves at once, and when such is the case, observation of minor points are of great value when tonnage is the main issue.

SPIRALS.

Without discussing the theory of the spiral as affecting railway grades, it should be said that the object of the spiral is twofold:

(1) To afford a run-off and a run-on from a level cross-section to a super-elevated cross-section.

(2) To ease the horizontal passage from a straight line to a curve.

It is evident that in passing from a level position to a superelevated position, when the inner rail of the curve is laid at grade, the center of gravity of the mass of the train must be raised through a distance equal to one-half the super-elevation. This is generally a minor rise, but in order to haul uniform tonnage this minor point should be carefully observed, especially where limiting conditions are found, such as places near the end of a long-continued effort. It has been proposed in the past that the inner rail be depressed a distance equal to one-half of the super-elevation, and the outer rail be raised the same amount. While this has been objected to by some railroad men, it can certainly be done and so maintained, and from a tonnage haul standpoint it is desirable. It is submitted that the railway of the future, which is scientifically operated, will find conditions such as these limiting their tonnage unless care is taken. While it might be said that refinements in the track are unimportant, it should be borne in mind that, in order to realize the full value of improvements, these matters must be taken into consideration. *A combination of correct conditions results in the most effective operation.*

REVERSE CURVES.

Curves that reverse without any tangent between them mean operating expense. Not only must the super-elevation change abruptly, but the trucks must change their position in the same manner.

It is considered good practice to leave room between the points of spiral for four freight cars to straighten up after they change direction.

On most new construction, provision is made for at least 1,000 ft. between curves, and this practice is recommended unless great expense is involved.

THE EFFECT OF POOR TRACK ON TRAIN HAUL.

In exactly the same way that a horse can haul a wagon better on an asphalt pavement than on a cobble stone road, so can a locomotive haul tonnage more easily on a good track than on a poor track. Without going very far into the discussion of track maintenance, it may be stated that from a tonnage standpoint good track consists of the following things:

(1) Mathematical alinement.
(2) Super-elevation conforming to the speed.
(3) An unyielding sub-grade.
(4) Heavy enough rail so that the depression under the ruling grade is small.
(5) Enough ties beneath the rail to transmit the load uniformly to the sub-grade.
(6) Deep enough ballast to secure good drainage and distribution of loading.
(7) As much strength as is necessary.

It is easy to see that if a train is hauled along a roadway that is constantly pressing down the rails, it is literally climbing a hill all the time. It might be possible to submit some figures as to what was the effect of first-class track on train load, but inasmuch as specific figures denote scientific observation, it is thought best to confine the present statements to personal observation.

It has been observed that on a certain branch line, which was under construction, the work engine had difficulty at first in handling eight cars of ballast. During the ballasting, the surface was very bad, and the alinement poor. As each section of the line became ballasted, the work engine was gradually able to haul more cars until it was finally able to haul 20. On the main line of the same division, where the same grade ruled the tonnage, this same engine could haul 25 of these cars. The case cited represents the effect of improving line and surface, and this can be readily understood by anyone who has had the experience of driving an automobile over a bad road. As the refinements of surface are gradually attained, the effect becomes noticeable at once in the speed of the tonnage trains, irrespective of hauling increased tonnage.

A mountain grade of 116 ft. to the mile (2.2 per cent.) and 12 miles long was in bad shape, due to poor drainage and dirty ballast. It was determined to overhaul the grade, giving the ballast a thorough cleaning and repairing the drainage. After setting line and surface stakes, the engineers were accustomed to board the freight trains going up the grade on their way home at night, doing so with ease on account of the slow speed of the train. As the work progressed, and the track came to better line and surface, the speed of these trains so improved that the engineers had to slow them down to get aboard, until this procedure was stopped by the Superintendent.

Inasmuch as the power of a locomotive can be translated into either tonnage or speed, the effect of the better surface of the track can readily be seen.

EFFECT OF TUNNELS.

Many railroads are suffering to-day on account of the fact that during the early days of construction it was not thoroughly realized that a tunnel might be a limiting feature. The following are the causes of the limiting effect of tunnels:

(1) A tunnel is dark, making the engine crew less confident.
(2) A derailment in a tunnel is almost sure to result in serious damage and loss.
(3) The heat in long tunnels, especially if of small section, is intense.
(4) The track conditions, such as line and surface, are never as good as on the outside.
(5) The rail is generally damp, causing either the excessive use of sand, or the slipping of drivers.
(6) Drainage in tunnels is usually bad, and difficult to improve.
(7) There are usually speed restrictions in tunnels.
(8) It was formerly the practice to carry maximum grades through tunnels in order to shorten them. This serious defect in many cases makes tunnels the ruling points.
(9) In tunnels of small section the use of helper engines is undesirable on account of the heat.
(10) The smoke and gas add to discomfort of operation.
(11) The impracticability of firing in long tunnels causes a drop in steam pressure.

There have been many plans devised for tunnel ventilation. Most of them are successful under some circumstances, but none is successful under all conditions. Long tunnels are generally built by means of shafts, and these shafts are sometimes left open to aid the ventilation. If the heat in the tunnel is greater than that outside, shafts will help when the atmosphere is low in humidity. When the humidity is high, shafts make but little difference in tunnel conditions. This is unfortunate, as tunnels at such times are very foul. Disc fans used in the shaft will operate satisfactorily sometimes, but their efficiency seems to vary about the same as the open shaft. Pure air blown down shafts is successful at times, but if the shaft is near the center, it generally happens that only one end of the tunnel is cleared out, the air remaining stationary at the other.

The Churchill System of ventilation, by which pure air is blown through the tunnel from one end through nozzles fitted at the sides of the tunnel, is successful, if the enginemen operate the locomotive so that the smoke is blown ahead of the engine. If two engines are used ahead on a train, and it is necessary to work the second engine, the position of the front engineer is unbearable. If one engine is used in the rear and one in front, and the smoke and gas from the second engine reaches the first one, the front engine crew are in the same position as in the case of the double-header, but if the train is skilfully handled, the smoke and gas of the rear engine will not reach the head engine. In tunnels where

the grade inside is considerably less than the ruling grade, it is sometimes found possible to shut off one engine entirely, and in that case there is no difficulty, provided that the train does not move faster than the air current.

The natural tendency is to drive the engine as hard as possible through the tunnel on a heavy grade in order to get through quickly. The speed of the air currents in the Churchill System of ventilation in a tunnel a mile long usually averages about 8½ miles an hour over the whole distance. If the tunnel is being worked to anywhere near its capacity, the additional time in the tunnel may seriously limit the number of trains that may be put through it. It has been found, however, that if the tunnel is cleaned out by the ventilating apparatus before the passage of each train, there is little difficulty in getting through. As a rule, the engine crews prefer this method.

Double-track tunnels are of sufficient section so that there is little discomfort in a tunnel a mile long, even if the locomotive is fired all the way through. The practice in Europe has always been much better than that in the United States in that even with single-track tunnels their section has been large enough so that they are less uncomfortable than those in this country. Tunnel ventilation in Europe is largely restricted to the dilution of locomotive gas with plenty of fresh air, rather than driving the smoke and gas ahead of the engine.

In the construction of new tunnels, an effort should always be made to reduce the grade in the tunnel considerably below the ruling grade, so that there may be no need of touching the fire during the passage through the tunnel. Ample section to secure good conditions is essential. In this connection it should be noted that the effect of long single-track tunnels of narrow section on the ruling grade is to reduce the tonnage rating in the tunnel by 10 per cent. at least.

EFFECT OF THE LENGTH OF THE GRADE.

Primarily it should be said that the effect of the length of a ruling grade depends entirely on what speed it is necessary to make up that grade. Hardly any operating division has more than 40 per cent. of ruling grade in either direction. It is generally computed that a train must average ten miles an hour over a division of 100 miles in order to secure the best economy. The question of economical speed will be discussed later, but for the present discussion, ten miles per hour will be used for an example.

Assume a division with 40 miles of ruling grade, and 60 miles of either downhill or less than ruling grade. If eight miles per hour is averaged on the ruling grades, and 12 miles per hour averaged on the down grades and less than ruling grades, the run may be made in ten hours. If a grade is very short, following a stretch of either downhill or less than ruling grade, sufficient speed may be had at the bottom to carry the train over the top, even though the ascending grade be considerably more than the ruling grade. As the train goes up the hill, its speed will constantly decrease. The speed at the top of the hill must be such that

CORRECTION OF GRADES.

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the engine still has some margin between its maximum tractive effort and what is required of it. This result depends entirely on the speed of the train at the foot of the grade. Such a grade is called a "Momentum Grade," and, while most railroad men will say it is not safe to depend on momentum, it is probable that there is not an important railroad in the country where the locomotive engineers cannot tell of portions of the line that are operated in that manner, even though the officers of the railroad do not know it. Were it not for momentum, it is likely that many curves would prove to be stalling points that are now passed around with not much, if any, trouble. We are learning more every day about handling trains and power at low speeds, but it must be understood that these low speeds are only for use for short periods of time, and not for general practice over a whole run. When the grade is long enough for the train to become stretched out fully upon it, or, in other words, when the engine settles down to a constant speed with its maximum tonnage, the rating speed for that particular train becomes fixed. Without a rise in the steam pressure, the train cannot accelerate as long as the grade remains the same. If there is a large percentage of this character of line on the division, the rating speed must be considerably higher than if there are only one or two places. For instance, it may be possible to average seven miles per hour over one piece of grade, if that is the only piece on the division, because the difference in time should be made up on the rest of the division, but it would be manifestly improper to load an engine so that such a low speed would be made over the whole run. Not only the low speed, but the constant demand on the engine would be such that the fireman would play out, and a failure would be the result.

PROPER PERCENTAGE OF RATING.

It has been stated that a locomotive standing on a dry steel rail should be capable of exerting a pull on a spring balance equal to (approximately) one-fourth its weight on drivers. This amount can be increased by the application of some medium to increase the co-efficient of friction, such as sand, to about 35 per cent. (for momentary purposes only).

This same pulling power can be used to haul a train, including, of course, the engine and the tender itself.

Ratings in use are never as great as could be pulled by the locomotive utilizing a tractive power of one-fourth the weight on drivers.

The reason is apparent.

Time is the essence of rating, just as it is the prime factor in all railroading.

The governing question is—

> For how long a time must the locomotive be required to exert its maximum pull during any particular run?

If it is required to exert a maximum effort for only about five minutes at a time, the rating might be established for a maximum effort, provided that time for rest of man and recuperation of fire elapses between the periods of maximum effort.

If maximum ratings were established for divisions where the ruling grades were long enough to require maximum effort for some time, the following conditions would have to be combated:

(1) Poor draft, owing to slow exhaust.
(2) Poor fire on account of poor and intermittent draft.
(3) Dirty fire on account of imperfect combustion.
(4) Tired fireman on account of heavy work for a long time.
(5) Steam failure.
(6) Stalling.

This is ordinarily the result of taking steam at full stroke for a long period of time, with a coal-burning engine.

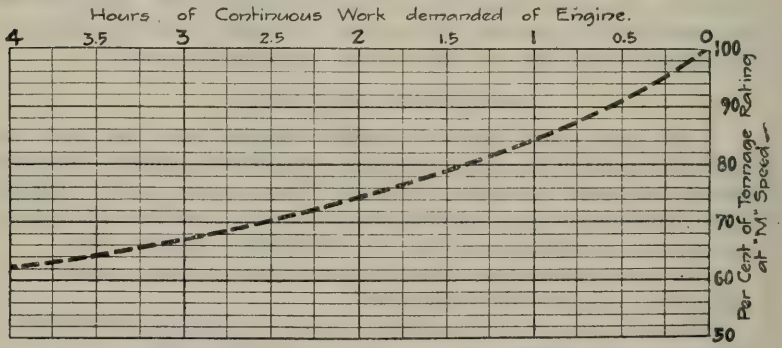
It will be understood that, if an engine is adjusted to working under such conditions, an improvement may be had compared with an engine which is utilized on general service.

The practical problem then is—

(1) How long can the *ordinary* fireman keep his fire in shape to deliver steam at full stroke?
(2) At what rate does his capacity deteriorate?
(3) At what rate can he maintain a steady and consistent performance for long periods of time?

In order to secure as uniform working conditions as possible, it is necessary to assign values as closely as possible to these rates mentioned.

The attached plat will represent about *what is considered fair practice.*



"M" Speed is that speed at which boilers can supply steam at full stroke based on a coal consumption of 4,000 pounds per hour.

This diagram is intended to show how much a rating should be reduced on account of continued demand on both fire and machine.

The curve shows what is fair practice in this direction.

In order to apply the chart, find out how long a time it is feasible and practical for the locomotive to consume in ascending the ruling grade, and taking that time on the chart, follow up the line and see what percentage of full rating may be given the engine. It is evident that when the percentage of rating gets as low as 60, it would pay to keep a full rating for the ruling grade with an assisting engine to avoid penalizing all the rest of the run improperly.

When the ruling factor in the operation is to conserve power, the greatest number of ton miles per engine mile is the figure to work for. This, however, will not always produce the lowest cost per ton mile.

At times there is a shortage of train crews and a surplus of power. In this case it becomes imperative to make the greatest number of ton miles per train mile. This nearly always shows the greatest economy of movement.

ADHESION TO RAIL.

An engine cannot do work and overcome train resistance unless it can transmit its cylinder work to the rail by means of adhesion due to the weight of the engine and the friction between wheel and rail.

It would seem as if there are so many reasons why a locomotive cannot haul tonnage up to its rated tractive power, that there would be nothing left.

Fortunately, however, there are ways to overcome some of the difficulties and there are times when they are not all active.

The adhesion of the wheels to the rails may be reduced by a number of circumstances as follows:

(1) Moisture acting as a lubricator.
(2) Frost.
(3) Grease.
(4) Poor rail surface.
(5) Manganese or other metals in the steel.
(6) Excessive super-elevation, throwing too much weight on one side.
(7) Inability to use sand.

(1) Moisture.—It is a well-known fact that a rail which is damp or only slightly wet will cause slipping of drivers. If, however, the rail is thoroughly wet so that the grease is washed off, leaving a clean rail, the adhesion is not appreciably reduced.

(2) Frost.—Frost is expensive. It is not only caused by low temperature, which in itself reduces the amount of steam that gets to the cylinder, but it lays on top of the rail and causes slipping by interposing a lubricating film between the driving wheel and the rail.

(3) Grease.—All rails are greasy and sooty. Grease or soot reduces the adhesion between the wheel and rail. Frequent rains will clean the rails.

(4) Poor Rail Surface may be caused by—

(1) Poor sub-grade.
(2) Worn rails.
(3) Insufficient work done on track to keep it in condition.

Firm strong track with as near perfect line and surface as is practical will permit the hauling of heavier trains than is possible on poor track.

Wheels slip easily on rails that give way beneath the weight of the engine.

(5) Manganese or Other Metals in the Steel.—Driving wheels slip more easily on manganese steel (such as in crossing frogs) than on

ordinary rail. This has been observed. The co-efficient of friction is reduced.

(6) EXCESSIVE SUPER-ELEVATION.—When the weight of a locomotive is thrown more on one side than on the other, part of the effort of the engine is made less than it would be if the engine were balanced.

The work done by the engine is theoretically about the same, but the resistances set up in both engine and train are increased, resulting in a loss.

(7) INABILITY TO USE SAND.—It often happens that when an engine is on a curve, the sand does not flow well on the rail. If the sand is needed, failure at a critical time results. Further, all engines are not equipped with back sanders, making it impossible to deliver maximum power when backing up.

Inasmuch as the adhesion of the wheels to the rail is a most important factor, these points should always be given full weight. If an engine is steaming properly, the co-efficient of adhesion generally is the determining factor when it comes to stalling.

ADJUSTED TON MILEAGE STATISTICS.

Assuming that, for rating purposes, the resistance formula, $R = 2.2\ T + 122\ C$, is correct, the resistance of a 20-ton car and a 70-ton car on different grades is as follows:

TABLE SHOWING THE RATIOS OF RESISTANCE AND BAR WEIGHTS WHEN THE LATTER DOES NOT INCLUDE THE ADJUSTMENT.

Rate of Grade, Per Cent.	Resistance of		Ratio of Resistance, Per Cent.	Ratio of Car Weights, Per Cent.
	20-ton Car, Pounds	70-ton Car, Pounds		
Level	166	276	60	20.5
.1	206	416	50	20.5
.2	246	556	44	20.5
.3	286	696	41	20.5
.4	326	836	39	20.5
.5	366	976	37	20.5
.6	406	1116	36	20.5
.7	446	1256	35	20.5
.8	486	1396	35	20.5
.9	526	1536	34	20.5
1.0	566	1676	34	20.5
1.1	606	1816	33	20.5
1.2	646	1956	33	20.5
1.3	686	2096	32	20.5
1.4	726	2236	32	20.5
1.5	766	2376	32	20.5
1.6	806	2516	32	20.5
1.7	846	2656	32	20.5
1.8	886	2796	32	20.5
1.9	926	2936	31	20.5
2.0	966	3076	31	20.5
2.2	1046	3356	31	20.5
2.5	1166	3776	30	20.5
3.0	1366	4476	30	20.5

Without a knowledge of train resistance under different conditions of car weight, it might be supposed that gross tonnage multiplied by the distance hauled would form the most accurate measure of work accomplished. The cost per gross ton mile would then be a measure of efficiency of operation.

However, this is not true since it takes 60 per cent. of the power to haul a 20-ton empty car on a level as it does to haul a 70-ton loaded car, while the empty car is less than 30 per cent. of the weight of the loaded car.

It, therefore, follows that as a measure of the cost of performed work the gross ton mileage alone is not an adequate basis of comparison.

If, however, the adjustment figures are added to the weight of the car, the results become comparative at once, as may be seen by the following table:

TABLE SHOWING COMPARISON BETWEEN THE RATIO OF RESISTANCE AND THE RATIO OF CAR WEIGHTS WHEN THE LATTER INCLUDES THE ADJUSTMENT.

Rate of Grade, Per Cent.	Adjustment	Ratio of Car Wgts., Per Cent.	Resistance of		Ratio of Resistance, Per Cent.
			20-ton Car	70-ton Car	
Level	54	60	166	276	60
0.1	29	50	206	416	50
0.2	20	44	246	556	44
0.3	15	41	286	696	41
0.4	12	39	326	836	39
0.5	10	37	366	976	37
0.6	8.5	36	406	1116	36
0.7	7.5	35	446	1256	35
0.8	6.7	35	486	1396	35
0.9	6.0	34	526	1536	34
1.0	5.4	34	566	1676	34
1.1	5.0	33	606	1816	33
1.2	4.6	33	646	1956	33
1.3	4.3	32	686	2096	32
1.4	4.0	32	726	2236	32
1.5	3.7	32	766	2376	32
1.6	3.5	32	806	2516	32
1.7	3.3	32	846	2656	32
1.8	3.1	32	886	2796	32
1.9	2.9	31	926	2936	31
2.0	2.8	31	966	3076	31
2.2	2.6	31	1046	3356	31
2.5	2.2	30	1166	3776	30
3.0	1.8	30	1366	4476	30

It is not claimed that this method is absolutely accurate, as the adjustment can only be made for one grade on a division without employing too expensive assistance to get the data together.

The method of using adjusted ton mileage will give a fair measure of the cost of operation, and will be especially valuable in such items as depend on work done, such as fuel, and repairs to locomotives.

RATING THE LOCOMOTIVE.

What follows about the steam locomotive merely shows the application of what has already been written by Mr. A. K. Shurtleff on the methods used by him in computing the available tractive power of locomotives. It has been somewhat amplified, diagrammed and worked down to a form for easy application.

It can be testified that his methods are of great practical value.

Ten per cent. increase over the rating tractive power may be safely used for superheater engines if well handled and in good condition.

THE LOCOMOTIVE.

The boiler of any steam locomotive may generate steam at a certain rate, which is assumed for rating purposes. The cylinders of a locomotive

use the steam generated by the boiler. This steam is used to push a piston back and forth. If the steam enters one end of the cylinder, under full boiler pressure, and pushes the piston forward the entire length of the cylinder, and then entering the other end, pushes the piston back the entire length of the cylinder, two full cylinders of steam have been used.

It is evident that, if two full cylinders of steam are used for every forward and back motion of the piston, the amount of steam used per hour is the product of the number of full motions of the piston and the volume of the cylinder.

It can be readily understood that, as the number of piston movements increases in a given space of time, it is impossible for the boiler to generate steam fast enough to supply a cylinder full for each movement. So it is that three-fourths of a cylinder full is furnished, or one-half, or one-quarter, depending on the speed of the piston.

By means of a valve controlled by a lever, the steam supply can be cut off at any given portion of the piston stroke.

When the steam is cut off at one-half the piston stroke, it expands rapidly to the end stroke when it goes through an exhaust pipe. However, as the steam expands, its pressure decreases.

It should be understood that, since the boiler can produce steam only at a given rate of speed, steam can be used only at a given rate. In other words, it can be used in large quantities slowly, or in small quantities rapidly.

Thus it is that:

(1) A locomotive will deliver large cylinder tractive power at low speed, or,

(2) A locomotive will deliver small cylinder tractive power at high speed.

The tractive power of a locomotive is usually considered as being the number of pounds of pull it can exert on the load it has to haul. For example: If a locomotive were hitched to a large spring balance and started, the tractive power of the locomotive would be registered on the spring balance.

If the power of the cylinder were so great that the pull on the spring balance was greater than one-fourth of the weight on the drivers of the locomotive, the driving wheels would slip on the rails. But, if the adhesion of the wheels to the rails was increased by the use of sand, the engine could exert a pull equal to about one-third of the weight on drivers before it slipped, provided it had steam pressure to do so.

This slipping regulates the proportion of cylinder power for a given weight on drivers of a locomotive.

It should be understood that, as a general proposition, only at the slow speed at which the steam is supplied by the cylinder full is the maximum tractive power of one-fourth weight on drivers realized. As the speed increases the tractive power diminishes. If, however, the boiler capacity were such as to supply steam at full stroke at high speed, the engine could exert a tractive power equal to one-fourth the weight on drivers at that speed.

The advantage of the electric motor is illustrated by this point. The motor can deliver tractive power equal to one-fourth weight on drivers at higher speed than the steam locomotive, provided it receives the current.

The oil burner, too, is a better performer than the coal burner.

Out of the power which is generated by the boiler, the locomotive must move itself and tender. About 7 per cent. of its power is used in this way. What remains may be used for work behind the tender.

Since it takes more power to start a train than it does to keep it moving, some allowance has to be made for starting resistances.

Further allowance has to be made to overcome the resistance offered by the mass of the train to increasing speed. If there is only a small allowance made for this, the speed can be increased slowly. However, the allowance made for starting resistances may be utilized for acceleration after the starting resistance has been dissipated.

Further allowances are made for the inability of the fireman to maintain full steam pressure for long periods of time.

As a rule, if maximum effort is required of the fireman for longer than a half hour at a time, reductions must be made in the train load.

Depending on the character of the railroad, ratings of engines in slow performance are usually based on using from 60 per cent. to 85 per cent. of the cylinder tractive power behind the tender.

AUTOMATIC STOKER.

The development of the stoker during the last two years has demonstrated that it is going to be of great value, although it is by no means a perfect machine.

MIKADO TYPE SUPERHEATER OF TRACTIVE FORCE OF 50,000 LBS.

Some remarkable results have been secured. On one test, carried on by an expert with a coal burning locomotive, steam was furnished the cylinders at full stroke at 18 miles per hour for a period of thirty minutes.

The average fireman has not yet been able to get such results as these.

Observation of stoker tests has shown the following:

(1) Proper coal must be furnished in order to secure quick combustion.

(2) The parts of the stoker must be strong enough so that rough handling will not destroy them.

(3) Firemen should be thoroughly educated in their use.

(4) Provision should be made for a quick change to hand firing in case of failure of stoker.

(5) The parts should be well lubricated. The chief value of the stoker lies in the fact that it can fire coal at a faster rate than a man. The coal, if burned, produces heat, and, therefore, steam at a faster rate.

The tractive power at rating speed is, therefore, greater, and either the tonnage rating may be raised or the speed of movement improved.

LOCO. SERIES. In 14 Sheets. SHEET No. 1.

METHOD OF CALCULATING LOCOMOTIVE CHARACTERISTICS DRAW BAR PULL AND TONNAGE RATING

GIVEN DATA:

TYPE OF ENGINE _____

CLASS _____

SIZE OF DRIVERS _____

DIAGRAM (drawn to scale of 1 in. = 20 ft.) _____

Weight on DRIVERS _____

Weight on TRUCKS (Engine) _____

Total Weight of ENGINE _____

Weight of TENDER _____

Total Weight of ENGINE & TENDER _____

Capacity of TENDER — Tons of Coal _____ — Gallons of Water _____

BOILER PRESSURE _____ lbs.

CYLINDERS (dia. x stroke) _____ "dia. X _____" length of stroke.

HEATING SURFACE (in sq. ft.)
- Tubes _____ sq. ft.
- Firebox _____ sq. ft.
- Superheater _____ sq. ft.
- TOTAL _____ sq. ft.

GRATE AREA _____

RATIO OF HEATING SURFACE to GRATE AREA _____

NOTES: _____

CALCULATED CHARACTERISTICS:-

From the above "GIVEN DATA" the Method of Figuring "LOCOMOTIVE CHARACTERISTICS" with the use of the following charts and tables is as follows:-

TABLE I:- AVERAGE EVAPORATION IN LOCOMOTIVES:- Sheet No. 7. This table is shown graphically on Sheet No 8, and intermediate values can be interpolated.

TABLE II:- WEIGHT OF STEAM used in ONE FOOT OF STROKE:- Sheet No. 7; graphic on Sheet No 9.

TABLE III:- VALUE OF COEFFICIENT "C" :- Sheet No 7; shown graphically on Sheet No 10.

TABLE IV:- MAXIMUM CUT-OFF & STEAM PER I.H.P. HOUR :- Sheet No 11; graphic on same sheet.

TABLE V :- PER CENT OF C.T.P. for MULTIPLES of "M":- Sheet No. 12; graphic on same sheet.

TABLE VI :- TRACTIVE POWER for ONE H.P. at VARIOUS SPEEDS:- Sheet No. 13; graphic on same sheet.

TABLE VII:- FORMULAE for LOCOMOTIVE RESISTANCES. AIR RESISTANCE shown graphically and is also tabulated:- Sheet No. 14.

1. Assumed Coal Consumption _____ lbs. per hour.
2. Value of Coal _____ B.T.U.
3. Heating Surface _____ sq. ft.
4. Pounds of coal per sq. ft. of Heating Surface per hour is ① / ③ = _____ lbs. per hour.
5. Pounds of steam production per pound of coal _____ pounds.
   → *Using ② and ④, this quantity can be gotten directly from* TABLE I.
6. Total Hourly Steam Production is ① _____ X ⑤ _____ = _____ lbs. per hour.
7. Steam Production per minute is ⑥ / 60 = _____ lbs. per min.
8. Weight of Steam used in One Foot of Stroke is _____ lbs.
   → *Taking from the "GIVEN DATA" above the Boiler Pressure of _____ lbs. and Diameter of Cylinder = _____ inches and applying them to* TABLE II, *quantity ⑧ can be gotten directly.*
9. Length of Stroke from "GIVEN DATA" = _____ inches, which divided by 12" = _____ ft.
10. Weight of Steam used per Stroke is ⑧ _____ lbs. X ⑨ _____ ft. = _____ lbs.
11. Number of Cylinders full of Steam per Revolution of Drivers is _____
    For Simple and Four Cylinder Compounds this quantity = 4. and for Two Cylinder Compounds is equal to 2.
12. Steam Consumption per Revolution of Drivers is ⑪ _____ X ⑩ _____ lbs. = _____ lbs.
13. Number of Revolutions per Minute of Drivers *at which the Boiler will furnish* Steam at Full Stroke is ⑦ / ⑫ = _____ R.P.M.

Loco. Series. In Sheets SHEET No. 2.

CALCULATED CHARACTERISTIC:- (Continued from Sheet No. 1)

14. Velocity of Locomotive in Miles per Hour corresponding to ⑬ _____
Revolutions per Minute of Drivers. *Referring to* TABLE III, *and using the diameter of Drivers* = _____ *inches (see* GIVEN DATA), *Coefficient "C" is obtained directly and* = _____; *and our quantity* ⑭ = ⑬ / "C" = _____ m.p.h.

15. VALUE OF "M" IN MILES PER HOUR is ⑭ _____ m.p.h.
→ *EXPLANATION:- The speed of the locomotive (in miles per hour) at which the boiler will furnish steam at full stroke is known as "M"; and quantity* ⑮ = ⑭

16. Steam Consumption per Indicated Horse Power Hour at Full Stroke. *Using* TABLE IV *and velocity* = 1.0"M", *also boiler pressure* = ___ lbs. *(see* GIVEN DATA), *this quantity* ⑯ *is obtained directly and is* _____ pounds.
CAUTION:- Table IV is based on Boiler Pressure of 200 lbs; hence, for other pressures correct tabular quantity by percentages shown. For Simple Locomotives use column "Simple Locomotives"; and the column "Compound Locomotives" for Compounds.

17. Total Indicated Horse Power of the Locomotive is ⑥ / ⑯ = _____ I.H.P.

18. CYLINDER TRACTIVE POWER OF THE LOCOMOTIVE AT FULL STROKE = _____ lbs.
→ *Method:- Referring to* TABLE VI *and using the quantity* ⑮ _____ m.p.h., "Pounds of Tractive Power per Horse Power" *is obtained directly and is* _____ POUNDS PER HORSE POWER; *this quantity* _____ POUNDS PER H.P. × ⑰ _____ = _____ lbs, *which is the quantity desired.*

19. Rated by Makers _____ at _____ lbs. Tractive Power.

METHOD OF CALCULATING DRAW BAR PULL:-

Having arrived at the ⑮ VALUE OF "M" IN MILES PER HOUR as _____ m.p.h. and ⑱ CYLINDER TRACTIVE POWER OF LOCOMOTIVE AT FULL STROKE as _____ pounds, we are now prepared to calculate DRAW BAR PULL at various speeds and grades.

VELOCITY IN MULTIPLES OF "M" | % OF CYLINDER TRACTIVE POWER | CYLINDER TRACTIVE POWER

FIRST:- Quantity ㉒ _____ is known as 1.0"M" and multiples of "M" for various speed is obtained by dividing VELOCITY IN MILES PER HOUR by VALUE OF "M" IN MILES PER HOUR, thus:-

VELOCITY IN MILES PER HOUR	VELOCITY ÷ M	MULTIPLE OF "M"
5	⑤ 5 mi. / ⑮ =	_____ ⑳
6	⑥ 6 mi. / ⑮ =	_____ ㉑
7	⑦ 7 mi. / ⑮ =	_____ ㉒
8	⑧ 8 mi. / ⑮ =	_____ ㉓
9	⑨ 9 mi. / ⑮ =	_____ ㉔
10	⑩ 10 mi. / ⑮ =	_____ ㉕
15	⑮ 15 mi. / ⑮ =	_____ ㉖
20	⑳ 20 mi. / ⑮ =	_____ ㉗
25	㉕ 25 mi. / ⑮ =	_____ ㉘
30	㉚ 30 mi. / ⑮ =	_____ ㉙
35	㉟ 35 mi. / ⑮ =	_____ ㉚

SECOND:- Using the Multiples of "M" just obtained and applying them to TABLE V (*being sure to use proper column for "Simple" or "Compound"*) the following percentages are obtained directly:-

VELOCITY IN MILES PER HOUR	MULTIPLE OF "M"	PER CENT OF C.T.P.
5	⑳ _____ =	_____ ㉛
6	㉑ _____ =	_____ ㉜
7	㉒ _____ =	_____ ㉝
8	㉓ _____ =	_____ ㉞
9	㉔ _____ =	_____ ㉟
10	㉕ _____ =	_____ ㊱
15	㉖ _____ =	_____ ㊲
20	㉗ _____ =	_____ ㊳
25	㉘ _____ =	_____ ㊴
30	㉙ _____ =	_____ ㊵
35	㉚ _____ =	_____ ㊶

FINALLY:- Using quantity ⑱ _____ lbs. Cylinder Tractive Power at "M" and multiplying by percentages, *CYLINDER TRACTIVE POWER AT ANY GIVEN SPEED* is gotten:-

VELOCITY IN MILES PER HOUR	C.T.P. at "M" (POUNDS)	PER CENT	CYLINDER TRACTIVE POWER (POUNDS)
5	⑱ _____ ×	㉛ _____ =	_____ ㊷
6	⑱ _____ ×	㉜ _____ =	_____ ㊸
7	⑱ _____ ×	㉝ _____ =	_____ ㊹
8	⑱ _____ ×	㉞ _____ =	_____ ㊺
9	⑱ _____ ×	㉟ _____ =	_____ ㊻
10	⑱ _____ ×	㊱ _____ =	_____ ㊼
15	⑱ _____ ×	㊲ _____ =	_____ ㊽
20	⑱ _____ ×	㊳ _____ =	_____ ㊾
25	⑱ _____ ×	㊴ _____ =	_____ ㊿
30	⑱ _____ ×	㊵ _____ =	_____ (51)
35	⑱ _____ ×	㊶ _____ =	_____ (52)

Loco. SERIES. Int Sheets. Sheet No. 3.

METHOD OF CALCULATING DRAW BAR PULL:- (continued from Sheet No. 2.)

The CYLINDER TRACTIVE POWER at Speeds just computed is equal to RESISTANCE IN POUNDS which the engine can overcome.

In order to find the *resistance capable of being overcome behind the draw bar* or "DRAW BAR PULL", there must be deducted from the Cylinder Tractive Power, the following Resistances:-

a. LOCOMOTIVE RESISTANCES.
b. RESISTANCE DUE TO GRADE
c. RESISTANCE DUE TO UNCOMPENSATED CURVATURE

a-LOCOMOTIVE RESISTANCES:-

Explanatory:- The axles which carry the Engine Drivers are known as "DRIVING AXLES" and *all other axles* are known as "TRUCK AXLES."

Hence, the Entire Weight of the Tender is carried on the "TENDER TRUCKS." The number of "TENDER TRUCK AXLES" is always equal to 'Number of Tender Truck Wheels' divided by 2

The 'Number of Engine Truck Axles' is always equal to (Total Number Engine Wheels minus the Number of Driving Wheels) divided by 2.

WEIGHT OF ENGINE & TENDER in Tons of 2000 pounds:-

53.- Weight on "Drivers" is _____ tons.
54.- Weight on "Engine Trucks" is _____ tons
55.- Total Weight of Engine is (53) plus (54) = _____ tons
56.- Weight on "Tender Trucks" is equal to Total Weight of Tender and is _____ tons
57.- Total Weight of Engine & Tender is (55) plus (56) = _____ tons

(See Sheet 1 "GIVEN DATA")

NUMBER OF AXLES:-

58.- Number of "Driving Axles" is _____
59.- Number of "Engine Truck Axles" is _____
60.- Number of "Tender Truck Axles" is _____
61.- Total Number of "Truck Axles" is (59) plus (60) = _____

(See Sheet 1. "GIVEN DATA")

RESISTANCES IN POUNDS:-

62.- Cylinder to Rim of Drivers.
18.7 X (53) _____ = (63) _____ lbs.
80 X (58) _____ = (64) _____ lbs
quantity (63) plus (64) = _____ lbs., which is (62) 62.

65.- Engine and Tender Trucks.
2.6 X (68)* _____ = (66) _____ lbs.
20 X (61) _____ (67) _____ lbs.
quantity (66) plus (67) = _____ lbs., which is (65) 65.

*Quantity (68) equals (54) _____ + (56) _____ or _____ lbs.

69 to 80 incl.- Head End or Air Resistance:-

The Head End or "Air" Resistance varies as the speed of the locomotive, and can be obtained directly from TABLE VII:-

4 m.p.h. = 4.00 lbs. (69)	7 m.p.h. = 12.25 lbs. (72)	10 m.p.h. = 25.00 lbs. (75)	25 m.p.h. = 156.00 lbs. (78)
5 m.p.h. = 6.25 lbs. (70)	8 m.p.h. = 16.00 lbs. (73)	15 m.p.h. = 56.00 lbs (76)	30 m.p.h. = 225.00 lbs. (79)
6 m.p.h. = 9.00 lbs. (71)	9 m.p.h. = 20.25 lbs. (74)	20 m.p.h. = 100.00 lbs. (77)	35 m.p.h. = 306.00 lbs. (80)

The above "a-LOCOMOTIVE RESISTANCES" deducted from the CYLINDER TRACTIVE POWER at speeds computed (Sheet No 2) will give the "DRAW BAR PULL ON LEVEL TANGENT (or 0.00% Grade) at corresponding speeds:

The Method is as follows: (continued on Sheet No. 4.)

Loco. SERIES. In Sheets. SHEET No. 4.

DRAW BAR PULL on LEVEL TANGENT:- (continued from Sheet 3)

81.-Total "Engine and Tender Resistances" (exclusive of Head End Resistance) in Pounds, equals the sum of (62) and (65), e.g:-

(62)_____lbs. + (65)_____lbs. = (81)_____lbs.

The CYLINDER TRACTIVE POWER at speeds computed (Sheet No2) minus (81)_____lbs., which is constant for all speeds, will give quantities from which must be deducted the Head End Resistance, which varies with the speed, the result being DRAW BAR PULL ON LEVEL TANGENT

Speed in Miles per Hour	5	6	7	8	9	10	15	20	25	30	35
Reference Number for CYL. TRAC. POWER	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)
CYLINDER TRACTIVE POWER											
Constant (81)											
CYL. TRAC. POWER − (81)											
Deducting "Head End"	6	9	12	16	20	25	56	100	156	225	306
Result is DRAW BAR PULL											
Reference Numbers for DRAW BAR PULL →	(82)	(83)	(84)	(85)	(86)	(87)	(88)	(89)	(90)	(91)	(92)

DRAW BAR PULL ON GRADE:- (See Sheet No.5.)

The "Draw Bar Pull on Grade" is obtained as follows:-

Having calculated the "Draw Bar Pull on Level Tangent" and using these quantities ((82) to (92) inc) as a base, deduct for each 0.10 per cent increase in grade quantity (93)_____lbs, derived as follows:-

93.- Resistance due to 0.10 % increase in grade is (57)___tons X 2 lbs = (93)_____lbs

└ This amount is to be deducted consecutively from quantities (82) to (92) inclusive, thus :-

Draw Bar Pull on Level Tangent − (93)_____lbs. = Draw Bar Pull on 0.10% Grade.

Draw Bar Pull on 0.10% Grade − (93)_____lbs. = Draw Bar Pull on 0.20% Grade,

and so on, until all grades are computed.

Note - TABULATE RESULTS ON SHEET No.5

TONNAGE RATING:-

Having obtained DRAW BAR PULL on various grades and at different speeds - the method of reducing DRAW BAR PULL to TONNAGE RATING is given on Sheet No 5 The results obtained are to be tabulated on Sheet No. 6.

FORMULAE (for reference):-

(Train) Resistance per Car on Level Tangent = 2.22 (Weight of Car in Tons) + 122

(Train) Resistance per Car due to Grade = 20 (Weight of Car in Tons) X per cent of Grade

$$\text{Tonnage Rating on Level Tangent} = \frac{\text{Draw Bar Pull on Level Tangent} - 122 \text{ pounds}}{2.22 \text{ pounds}}$$

$$\text{Tonnage Rating on Grade} = \frac{\text{Draw Bar Pull on Given Grade} - 122 \text{ pounds}}{20 (\text{per cent of Given Grade}) + 2.22 \text{ pounds}}$$

Locomotive Resistance due to UNCOMPENSATED curve = [(0.4 + 0.8 Degree of Curve) X (Tons on Drivers)] + [(0.4 + 0.4 Degree of Curve) X (Tons on Pony Trucks*)] + [(0.4 + 0.4 Degree of Curve) X (Weight of Tender in Tons)]. *Omit all Two Wheel Trucks

Train Resistance per Car for UNCOMPENSATED Curvature = (0.4 + 0.4 Degree of Curve x Weight of Car in Tons.

$$\text{Tonnage Rating on Grade Uncompensated Curve} = \frac{\text{Draw Bar Pull on Given Grade Uncompensated Curve} - 122 \text{ lbs}}{[20 (\text{Per Cent of Grade}) + 2.22] + [0.4 + 0.4 (\text{Degree of Curve})]}$$

Loco. SERIES Ire 14 Sheets. — Sheet No. 5.

DRAW BAR PULL OF _____ LOCOMOTIVE

(TYPE_____)

SPEEDS OF 5 TO 35 MILES PER HOUR

Coal Consumption = (1)_____lbs. per hour. Value of Coal = (2)_____B.T.U. Boiler Pressure = _____lbs.
Value of "M" = (15)_____miles per hour Cylinder Tractive Power at "M" = (18)_____lbs.

SPEED IN MILES PER HOUR		5	6	7	8	9	10	15	20	25	30	35
Multiples of "M"												
Per Cent of Cylind. Tractv. Power												
REFERENCE NO FOR D.B.P.		(82)	(83)	(84)	(85)	(86)	(87)	(88)	(89)	(90)	(91)	(92)
(94) 2.22	0.0											
Constant (93) →												
(95) 4.22	0.1											
(96) 6.22	0.2											
(97) 8.22	0.3											
(98) 10.22	0.4											
(99) 12.22	0.5											
(100) 14.22	0.6											
(101) 16.22	0.7											
(102) 18.22	0.8											
(103) 20.22	0.9											
(104) 22.22	1.0											
(105) 24.22	1.1											
(106) 26.22	1.2											
(107) 28.22	1.3											
(108) 30.22	1.4											
(109) 32.22	1.5											
(110) 34.22	1.6											
(111) 36.22	1.7											
(112) 38.22	1.8											
(113) 40.22	1.9											
(114) 42.22	2.0											
(115) 44.22	2.1											
(116) 46.22	2.2											
(117) 48.22	2.3											
(118) 50.22	2.4											
(119) 52.22	2.5											
(120) 54.22	2.6											
(121) 56.22	2.7											
(122) 58.22	2.8											
(123) 60.22	2.9											
(124) 62.22	3.0											

DIVISORS FOR REDUCING DRAW BAR PULL TO TONNAGE RATING. RATE OF GRADE. (PER CENT)

↑ TO REDUCE DRAW BAR PULL to TONNAGE RATING:- Subtract 122 pounds from the above Draw Bar Pull in pounds and divide the remainder by the divisor shown, the result being Tonnage Rating. (94) to (124) are the divisors to be used. TABULATE RESULTS ON SHEET NO. 6.

H.H.H (5)

Loco. Series. In 14 sheets Sheet No. 6.

TONNAGE RATING OF_____ LOCOMOTIVE.

(TYPE _____)

SPEEDS OF 5 TO 35 MILES PER HOUR.

(6)

Coal Consumption ①____ lbs. per hour Value of Coal = ②____ B.T.U. Boiler Pressure = ____ lbs.

Value of "M" = ⑮____ m.p.h. Cylinder Tractive Power at "M" = ⑱_____ lbs.

Adjustment in Tons per Car for different class ratings				GRADE PER CENT.	SPEED IN MILES PER HOUR										
					5	6	7	8	9	10	15	20	25	30	35
A	B	C	D		THEORETICAL RATING IN TONS										
54	81	108	135	LEVEL											
29	44	59	74	0.1											
20	30	40	50	0.2											
15	22	30	37	0.3											
12	18	24	30	0.4											
10	15	20	25	0.5											
9	13	18	22	0.6											
8	12	16	20	0.7											
7	11	14	18	0.8											
6	9	12	15	0.9											
5	8	10	13	1.0											
5	8	10	13	1.1											
5	8	10	13	1.2											
4	6	8	10	1.3											
4	6	8	10	1.4											
4	6	8	10	1.5											
4	6	8	10	1.6											
3	5	6	8	1.7											
3	5	6	8	1.8											
3	5	6	8	1.9											
3	5	6	8	2.0											
3	5	6	8	2.1											
3	5	6	8	2.2											
2	3	3	5	2.3											
2	3	3	5	2.4											
2	3	3	5	2.5											
2	3	3	5	2.6											
2	3	3	5	2.7											
2	3	3	5	2.8											
2	3	3	5	2.9											
2	3	3	5	3.0											

Use:—

"A" Rating for Temperatures over 35° F.

"B" " " Temp. from 20° to 35° F.

"C" " " " 0° to 20° F

"D" " " " below 0° F.

H.B.H.

Loco. SERIES. Int 14 sheets. Sheet No. 7.

TABLE I.

AVERAGE EVAPORATION in LOCOMOTIVE BOILERS

Burning BITUMINOUS and SIMILAR COALS of various qualities and for various quantities consumed per SQUARE FOOT of HEATING SURFACE per HOUR. Based on Feed-Water at 60°F. Boiler Pressure = 200#.

Note to Table I. The quantity of steam evaporated for intermediate quantities and qualities of coal can be found by interpolation.

ON BAD WATER DISTRICTS *deduct the following from tabular quantities:-*

For each 1/16 inch of accumulated scale 10%

For each grain per U.S. gallon of foaming salts in the average feed water 1%

Pounds of Coal per Sq. Ft. of Htg. Surf. per Hour	POUNDS of STEAM per POUND of COAL of Given Thermal Value.					
	15,000 B.T.U.	14,000 B.T.U.	13,000 B.T.U.	12,000 B.T.U.	11,000 B.T.U.	10,000 B.T.U.
0.8	7.86	7.34	6.81	6.29	5.76	5.24
0.9	7.38	7.07	6.57	6.06	5.56	5.05
1.0	7.31	6.82	6.34	5.85	5.36	4.87
1.1	7.06	6.59	6.12	5.65	5.18	4.71
1.2	6.82	6.37	5.91	5.46	5.00	4.55
1.3	6.59	6.15	5.71	5.27	4.83	4.39
1.4	6.37	5.95	5.52	5.10	4.67	4.25
1.5	6.17	5.76	5.35	4.94	4.52	4.11
1.6	5.97	5.57	5.18	4.78	4.38	3.98
1.7	5.79	5.40	5.02	4.63	4.25	3.86
1.8	5.61	5.24	4.86	4.49	4.12	3.74
1.9	5.44	5.08	4.71	4.35	3.99	3.63
2.0	5.27	4.92	4.57	4.22	3.86	3.51
2.1	5.12	4.78	4.44	4.10	3.75	3.41
2.2	4.97	4.64	4.31	3.98	3.64	3.31
2.3	4.83	4.51	4.19	3.86	3.54	3.22
2.4	4.69	4.38	4.07	3.75	3.44	3.13
2.5	4.56	4.26	3.95	3.65	3.34	3.04
2.6	4.44	4.14	3.84	3.55	3.25	2.96
2.7	4.32	4.03	3.74	3.46	3.17	2.88
2.8	4.21	3.93	3.64	3.37	3.09	2.80
2.9	4.10	3.83	3.55	3.28	3.01	2.73
3.0	3.99	3.73	3.46	3.19	2.93	2.66

VALUE OF COEFFICIENT "C" FOR CHANGING REVOLUTIONS PER MINUTE OF DRIVERS INTO VELOCITY IN MILES PER HOUR

TABLE III.

$$"C" = \frac{336.13}{\text{Diameter of drivers in inches}}$$

$$\text{Miles per hour} = \frac{\text{Revolutions per minute}}{"C"}$$

Dia.	"C"	Dia.	"C"	Dia.	"C"	Dia.	"C"
50"	6.72	58"	5.79	66"	5.09	74"	4.54
51"	6.59	59"	5.69	67"	5.01	75"	4.48
52"	6.46	60"	5.60	68"	4.94	76"	4.42
53"	6.34	61"	5.51	69"	4.87	77"	4.36
54"	6.22	62"	5.42	70"	4.80	78"	4.31
55"	6.11	63"	5.33	71"	4.73	79"	4.25
56	6.00	64"	5.25	72"	4.67	80"	4.20
57"	5.89	65"	5.17	73"	4.60	81"	4.15

B. & O. R. R.
TABLES I, II & III.
LOCOMOTIVE DATA.
Office of General Manager,
Baltimore, Md.

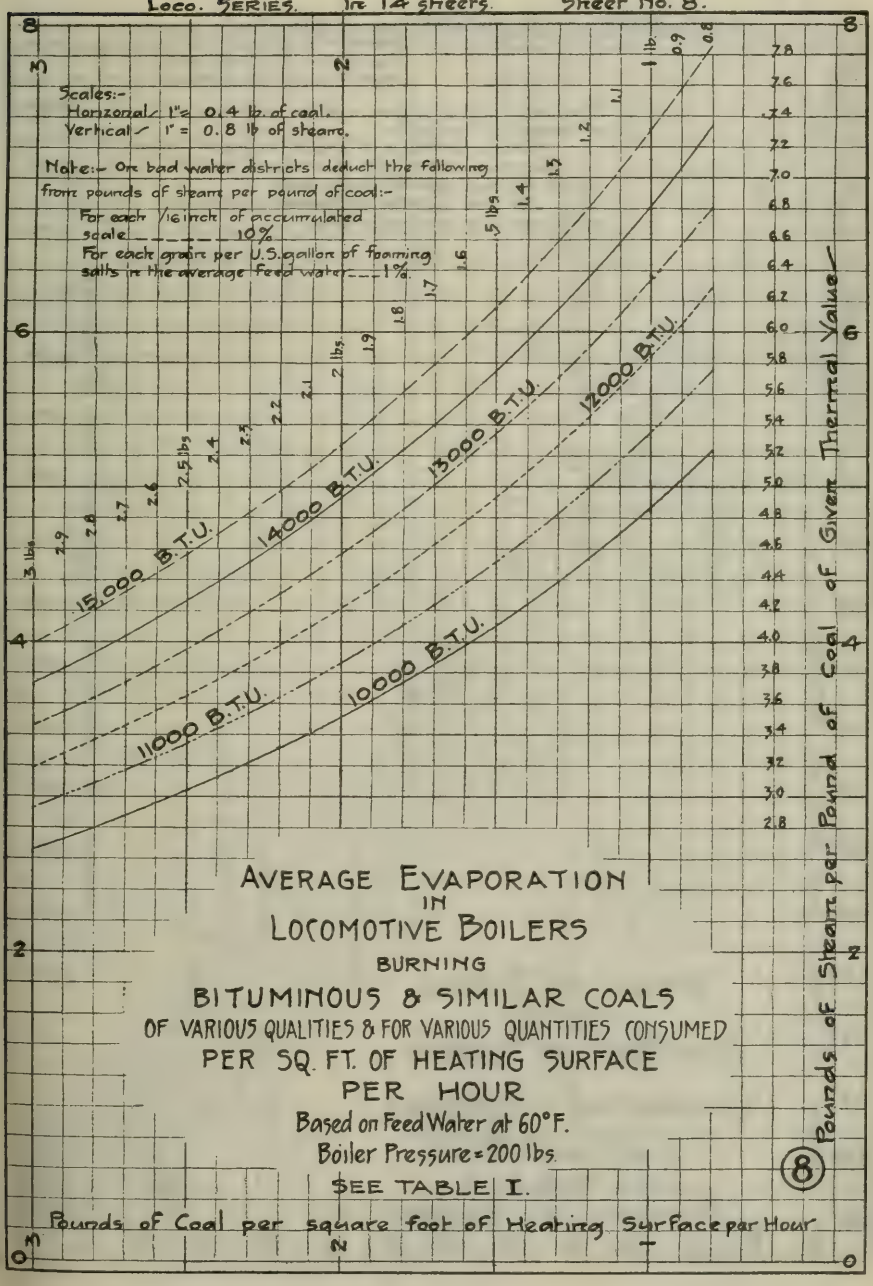
M. H. M.

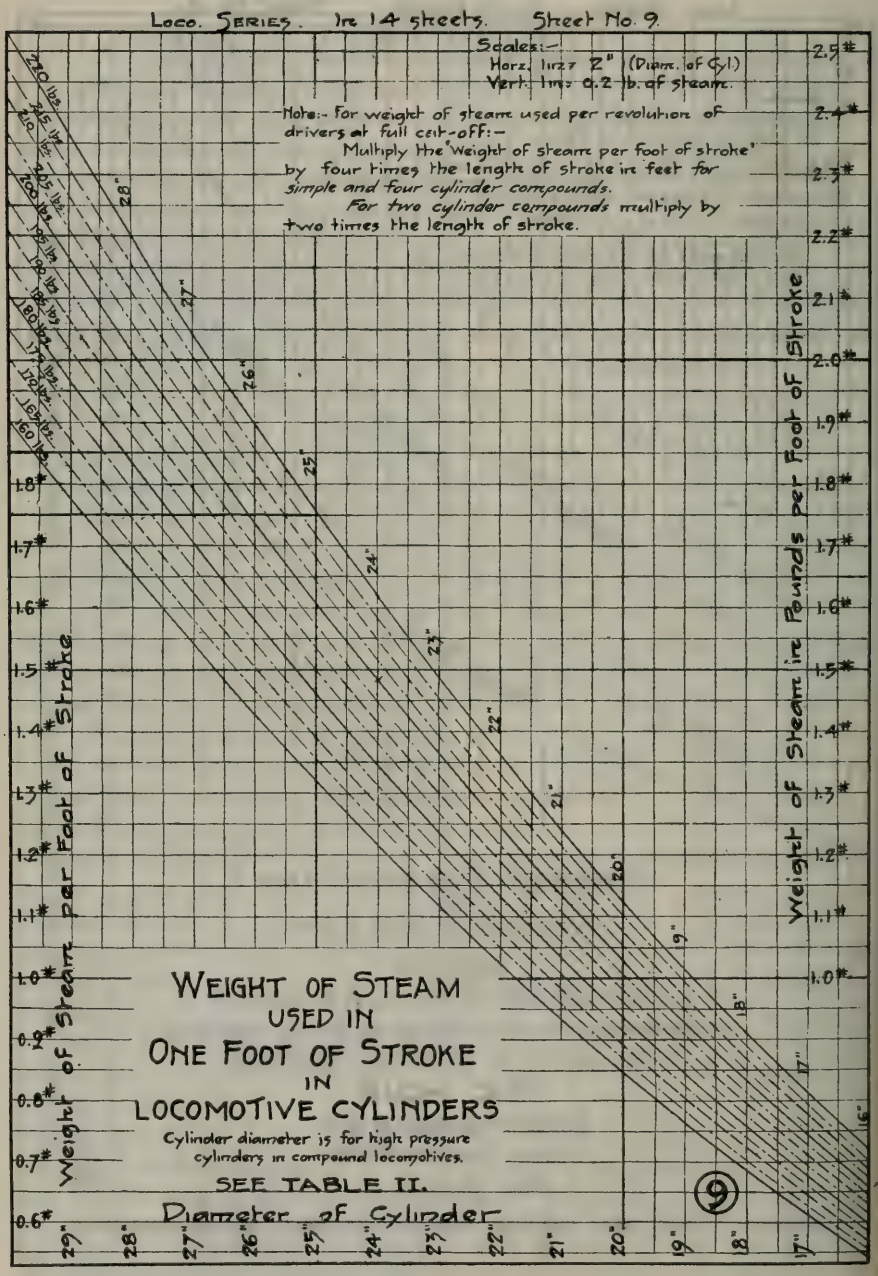
TABLE II - WEIGHT OF STEAM USED IN ONE FOOT OF STROKE IN LOCOMOTIVE CYLINDERS

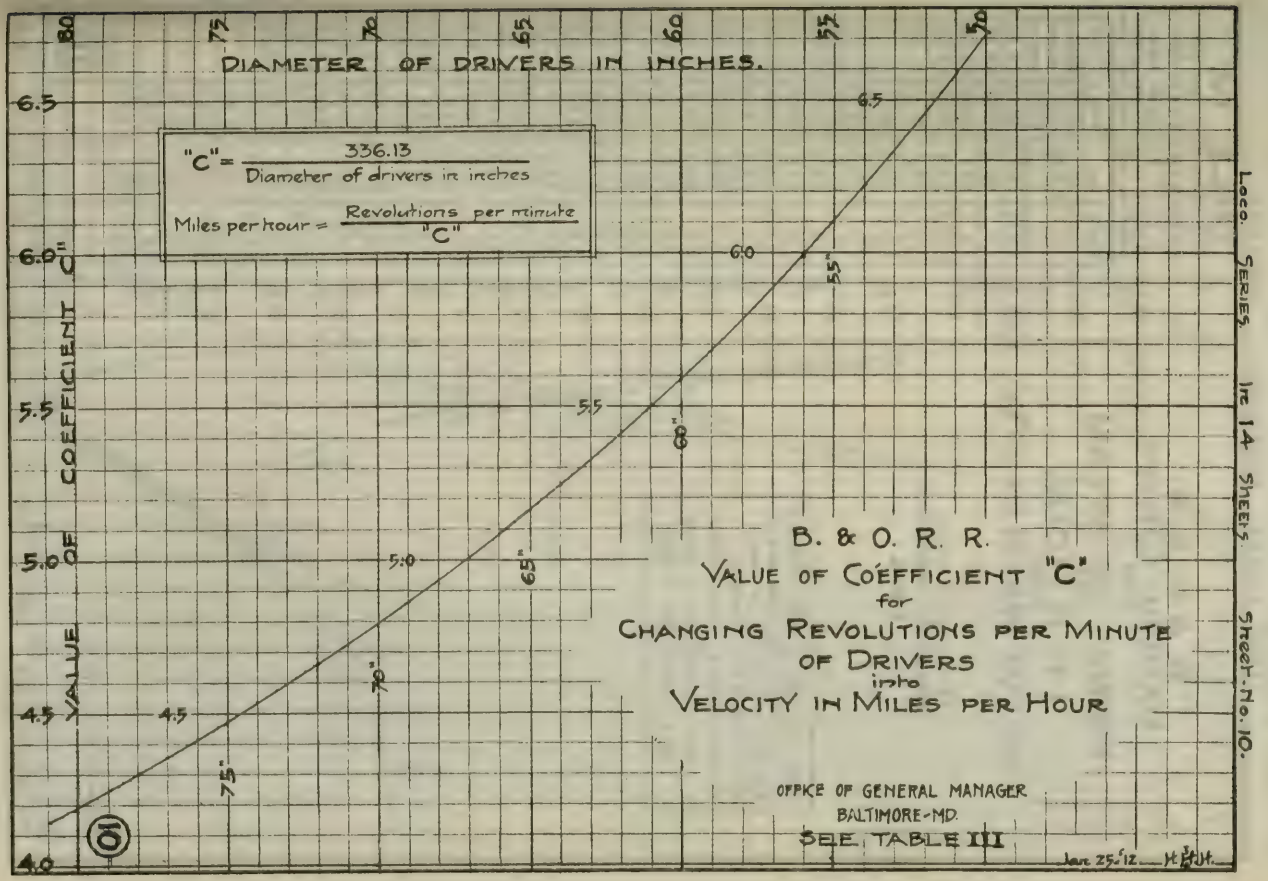
CYLINDER DIAMETER IS FOR HIGH PRESSURE CYLINDERS IN COMPOUND LOCOMOTIVES. FOR WEIGHT OF STEAM USED PER REVOLUTION OF DRIVERS AT FULL CUT-OFF:- MULTIPLY TABULAR QUANTITY BY FOUR TIMES THE LENGTH OF STROKE IN FEET. FOR SIMPLE AND FOUR CYLINDER COMPOUNDS. FOR TWO CYLINDER COMPOUNDS MULTIPLY BY TWO TIMES THE LENGTH OF STROKE.

Diam. of Cylinder in Inches	Area of Cylin. in sq. in. $= \frac{\pi D^2}{4}$	WEIGHT OF ONE CUBIC FOOT OF STEAM												
		.5266	.5154	.5043	.4932	.4825	.4717	.4611	.4505	.4398	.4291	.4186	.4082	.3978	.3875
		BOILER PRESSURE IN POUNDS												
		225	220	215	210	205	200	195	190	185	180	175	170	165	160
16	201.06		0.720	0.702	0.685	0.672	0.658	0.644	0.629	0.624	0.599	0.585	0.570	0.555	0.541
17	226.98		0.812	0.793	0.774	0.759	0.744	0.727	0.710	0.693	0.676	0.660	0.643	0.627	0.611
18	254.47		0.911	0.890	0.869	0.852	0.834	0.815	0.796	0.777	0.759	0.740	0.722	0.703	0.685
19	283.53		1.015	0.992	0.969	0.948	0.928	0.907	0.887	0.866	0.845	0.825	0.804	0.783	0.763
20	314.16		1.125	1.100	1.074	1.052	1.029	1.006	0.983	0.960	0.936	0.913	0.891	0.868	0.846
21	346.36		1.240	1.212	1.185	1.160	1.134	1.108	1.083	1.057	1.032	1.007	0.982	0.957	0.932
22	380.13		1.361	1.331	1.301	1.273	1.245	1.217	1.189	1.161	1.133	1.105	1.078	1.050	1.023
23	415.48		1.487	1.454	1.422	1.392	1.361	1.330	1.300	1.269	1.238	1.208	1.178	1.148	1.118
24	452.39		1.619	1.584	1.549	1.516	1.482	1.449	1.415	1.381	1.348	1.315	1.282	1.250	1.217
25	490.87		1.757	1.719	1.681	1.645	1.608	1.572	1.536	1.500	1.463	1.428	1.392	1.356	1.321
26	530.93		1.900	1.859	1.818	1.779	1.739	1.700	1.661	1.621	1.582	1.544	1.505	1.466	1.428
27	572.56		2.049	2.005	1.961	1.918	1.875	1.833	1.791	1.752	1.706	1.664	1.623	1.582	1.541
28	615.75		2.204	2.157	2.111	2.064	2.017	1.971	1.926	1.880	1.835	1.790	1.745	1.701	1.657
29	660.52		2.364	2.313	2.263	2.213	2.164	2.115	2.066	2.017	1.968	1.920	1.872	1.825	1.777
30	706.86		2.530	2.475	2.421	2.368	2.315	2.263	2.211	2.158	2.106	2.055	2.004	1.953	1.902

B. & O. R. R. - Office of General Manager - Baltimore, Md. Feby 23/1912. M.


Loco. SERIES. In 14 sheets. Sheet No. 8.
Scales:-
Horizontal- 1"= 0.4 lb. of coal.
Vertical - 1" = 0.8 lb of steam.
Note:- On bad water districts deduct the following from pounds of steam per pound of coal:-
For each 1/16 inch of accumulated scale 10%
For each grain per U.S. gallon of foaming salts in the average feed water ... 1%.
15,000 B.T.U.
14000 B.T.U.
13000 B.T.U.
12000 B.T.U.
11000 B.T.U.
10000 B.T.U.
AVERAGE EVAPORATION
IN
LOCOMOTIVE BOILERS
BURNING
BITUMINOUS & SIMILAR COALS
OF VARIOUS QUALITIES & FOR VARIOUS QUANTITIES CONSUMED
PER SQ. FT. OF HEATING SURFACE
PER HOUR
Based on Feed Water at 60° F.
Boiler Pressure = 200 lbs.
SEE TABLE I.
8
Pounds of Coal per square foot of Heating Surface per Hour
Pounds of Steam per Pound of Coal of Given Thermal Value


Loco. Series. In 14 sheets. Sheet No. 9.
Scales:—
Horz. 1in.= 2" (Diam. of Cyl.)
Vert. 1in.= 0.2 lb. of steam.
Note:- For weight of steam used per revolution of drivers at full cut-off:—
Multiply the "Weight of steam per foot of stroke" by four times the length of stroke in feet for simple and four cylinder compounds.
For two cylinder compounds multiply by two times the length of stroke.
210 lbs.
200 lbs.
190 lbs.
180 lbs.
170 lbs.
160 lbs.
28"
27"
26"
25"
24"
23"
22"
21"
20"
19"
18"
17"
16"
Weight of Steam per Foot of Stroke
Weight of Steam in Pounds per Foot of Stroke
WEIGHT OF STEAM
USED IN
ONE FOOT OF STROKE
IN
LOCOMOTIVE CYLINDERS
Cylinder diameter is for high pressure cylinders in compound locomotives.
SEE TABLE II.
9
Diameter of Cylinder


DIAMETER OF DRIVERS IN INCHES.
80
75
70
65
60
55
50
6.5
6.0
5.5
5.0
4.5
4.0
VALUE OF COEFFICIENT "C"
"C" = 336.13 / Diameter of drivers in inches
Miles per hour = Revolutions per minute / "C"
75"
70"
65"
60"
55"
B. & O. R. R.
VALUE OF COEFFICIENT "C"
for
CHANGING REVOLUTIONS PER MINUTE
OF DRIVERS
into
VELOCITY IN MILES PER HOUR
OFFICE OF GENERAL MANAGER
BALTIMORE-MD.
SEE TABLE III
Jan 25-'12
Loco. Series. Int 14 Sheets. Sheet No. 10.
101

Loco. SERIES. In 14 sheets. Sheet No. 11.

B. & O. R. R.
MAXIMUM CUT-OFF AND POUNDS OF STEAM PER I. H. P. HOUR FOR VARIOUS MULTIPLES OF "M"

"M" = maximum velocity in miles per hour at full cut-off.

1912

Note:- For STEAM PER I.H.P. HOUR for *other Boiler Pressures* take the following Percentages of values given in table IV. (or diagram)

160 lbs. = 103%	190 lbs = 100.6%
170 " = 102.1%	210 " = 99.5%
180 " = 101.3%	220 " = 99.2%

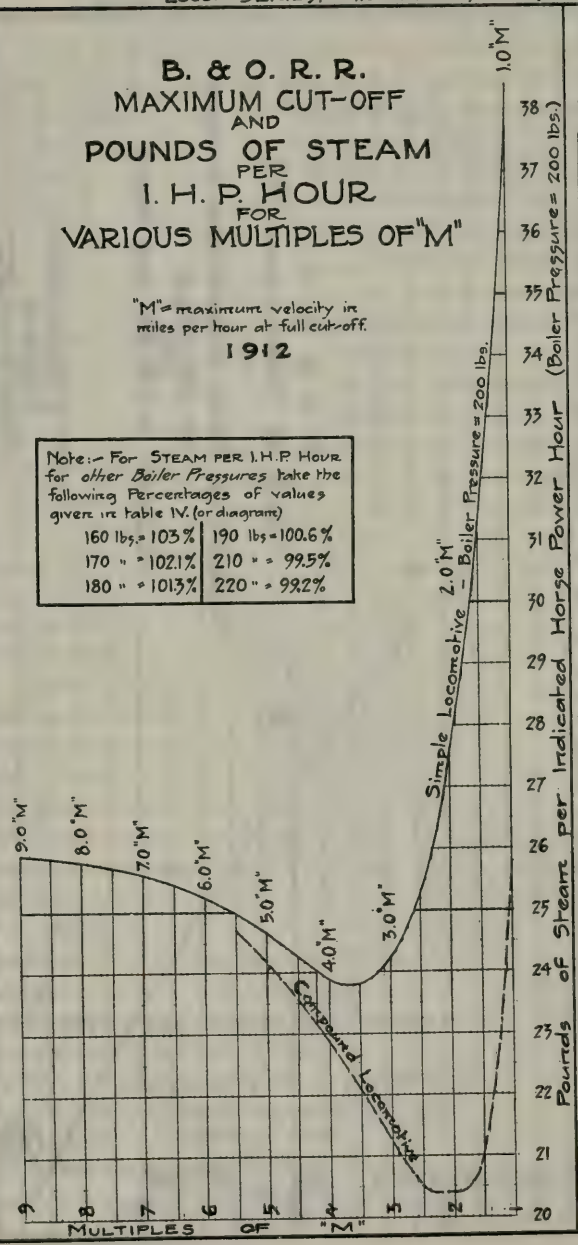


TABLE IV.

MAXIMUM CUT-OFF and POUNDS OF STEAM per I. H. P. HOUR FOR VARIOUS MULTIPLES OF "M" BASED ON BOILER PRESSURE = 200 lbs.

Velocity in Multiples of "M"	Per Cent of Cut-Off	Pounds of Steam per I.H.P. Hour	
		Simple Locomotives	Compound Locomotives
1.0 "M"	Full	38.30	25.80
1.1	94.4	36.46	24.36
1.2	89.1	34.89	23.24
1.3	84.3	33.56	22.35
1.4	79.7	32.41	21.65
1.5	75.4	31.40	21.14
1.6	71.4	30.49	20.77
1.7	67.7	29.67	20.52
1.8	64.3	28.93	20.40
1.9	61.0	28.25	20.40
2.0 M	58.0	27.62	20.40
2.1	55.2	27.05	20.40
2.2	52.6	26.52	20.40
2.3	50.1	26.06	20.40
2.4	47.8	25.67	20.40
2.5	45.7	25.32	20.47
2.6	43.7	25.02	20.60
2.7	41.8	24.76	20.73
2.8	40.1	24.54	20.88
2.9	38.5	24.37	21.04
3.0 "M"	37.0	24.22	21.21
3.2	34.2	24.00	21.57
3.4	31.8	23.85	21.93
3.6	29.8	23.8	22.27
3.8	28.0	23.8	22.57
4.0 "M"	26.4	23.87	22.85
4.25	24.7	24.05	23.22
4.50	23.3	24.24	23.56
4.75	22.1	24.44	23.85
5.0 "M"	21.1	24.64	24.15
5.5	19.5	24.98	24.70
6.0 "M"	18.4	25.20	
6.5	17.6	25.45	
7.0 "M"	17.1	25.60	
7.5	16.7	25.70	
8.0 "M"	16.4	25.80	
9.0 "M"	16.1	25.90	

(11)

OFFICE OF GENERAL MANAGER, BALTIMORE - MD. H. S. H.

Loco. SERIES. In 14 Sheets. Sheet No. 12,

B. & O. R. R.
PER CENT OF
CYLINDER TRACTIVE POWER
FOR
VARIOUS MULTIPLES OF "M"
"M" = Maximum Velocity in Miles per Hour at which Boiler Pressure can be maintained with Full Cut-Off.
1912

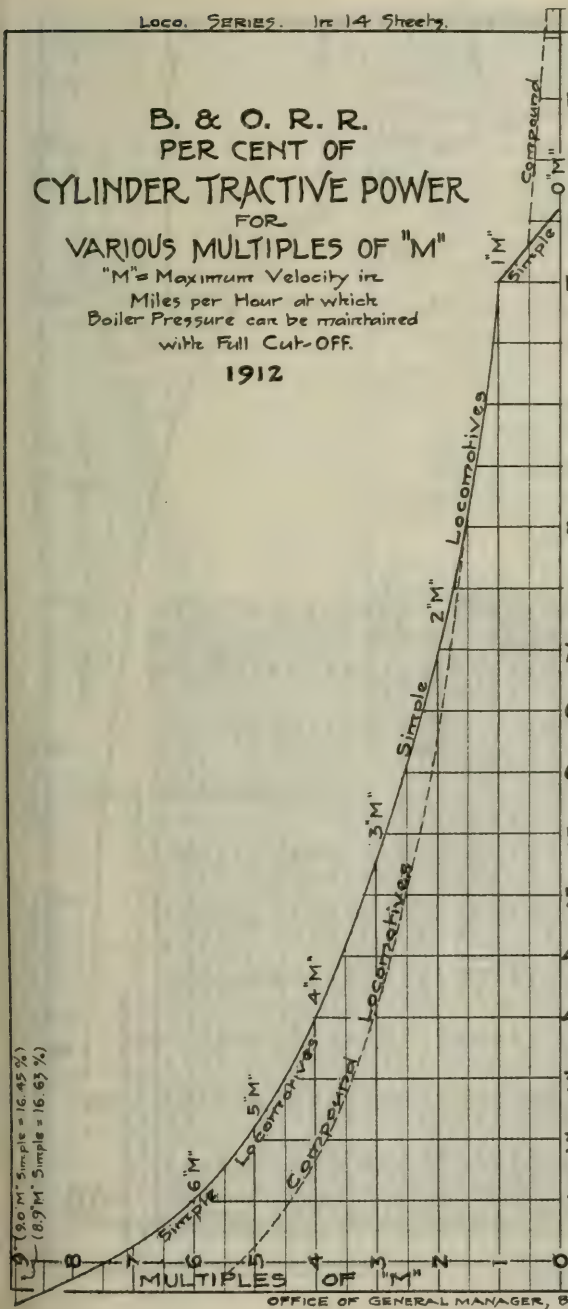


TABLE V.
PER CENT of CYLINDER TRACTIVE POWER for VARIOUS MULTIPLES OF "M"

Velocity in Multiples of M	Per Cent (Simple Locomotive)	Per Cent (Compound Locomotive)	Velocity in Multiples of M	Per Cent (Simple Locomotive)	Per Cent (Compound Locomotive)
0.0	106.0	135.0	4.8	32.59	22.48
0.5	103.0	103.0	4.9	31.82	21.92
1.0	100.0	100.0	5.0	31.11	21.38
1.1	95.57	96.28	5.1	30.42	20.87
1.2	91.53	92.55	5.2	29.75	20.37
1.3	87.83	88.83	5.3	29.10	19.89
1.4	84.46	85.12	5.4	28.48	19.43
1.5	81.37	81.40	5.5	27.87	18.99
1.6	78.55	77.68	5.6	27.33	
1.7	75.97	73.96	5.7	26.81	
1.8	73.60	70.25	5.8	26.30	
1.9	71.41	66.54	5.9	25.81	
2.0	69.37	63.21	6.0	25.34	
2.1	67.47	60.20	6.1	24.88	
2.2	65.67	57.48	6.2	24.44	
2.3	63.94	54.97	6.3	24.01	
2.4	62.22	52.68	6.4	23.59	
2.5	60.55	50.42	6.5	23.18	
2.6	58.92	48.16	6.6	22.79	
2.7	57.33	46.08	6.7	22.42	
2.8	55.78	44.10	6.8	22.06	
2.9	54.26	42.29	6.9	21.71	
3.0	52.78	40.57	7.0	21.38	
3.1	51.33	38.95	7.1	21.06	
3.2	49.91	37.42	7.2	20.75	
3.3	48.55	35.98	7.3	20.45	
3.4	47.24	34.66	7.4	20.16	
3.5	45.97	33.53	7.5	19.88	
3.6	44.75	32.40	7.6	19.61	
3.7	43.56	31.25	7.7	19.34	
3.8	42.39	30.10	7.8	19.08	
3.9	41.24	29.14	7.9	18.82	
4.0	40.10	28.24	8.0	18.57	
4.1	39.00	27.38	8.1	18.33	
4.2	37.96	26.56	8.2	18.09	
4.3	36.97	25.77	8.3	17.86	
4.4	36.03	25.03	8.4	17.64	
4.5	35.13	24.34	8.5	17.43	
4.6	34.26	23.69	8.6	17.22	(12)
4.7	33.41	23.07	8.7	17.01	
	SIMP	COMP	8.8	16.82	M.P.H.

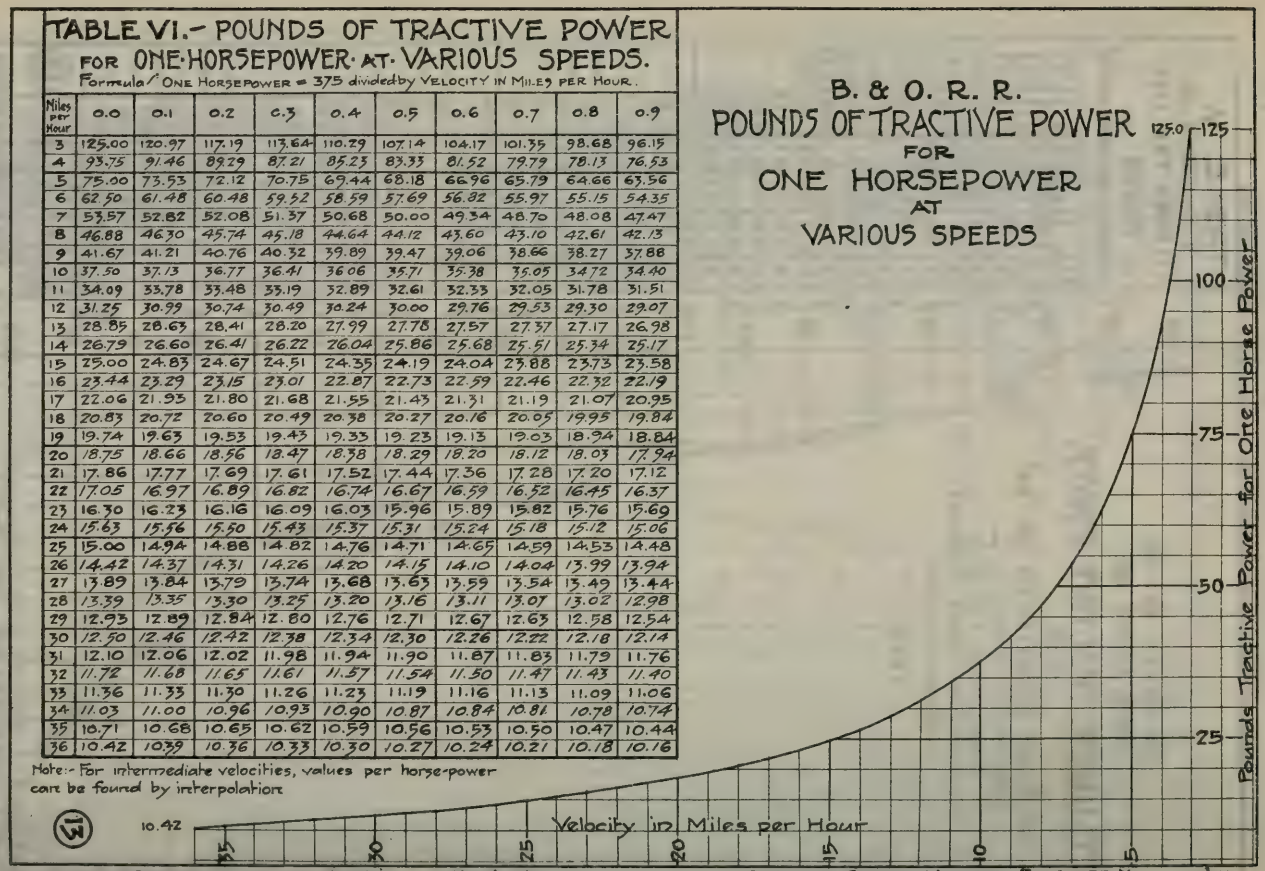
OFFICE OF GENERAL MANAGER, BALTIMORE, MD. Jan. 28/1912.

TABLE VI.– POUNDS OF TRACTIVE POWER FOR ONE-HORSEPOWER AT VARIOUS SPEEDS.

Formula: ONE HORSEPOWER = 375 divided by VELOCITY IN MILES PER HOUR.

Miles per Hour	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
3	125.00	120.97	117.19	113.64	110.29	107.14	104.17	101.35	98.68	96.15
4	93.75	91.46	89.29	87.21	85.23	83.33	81.52	79.79	78.13	76.53
5	75.00	73.53	72.12	70.75	69.44	68.18	66.96	65.79	64.66	63.56
6	62.50	61.48	60.48	59.52	58.59	57.69	56.82	55.97	55.15	54.35
7	53.57	52.82	52.08	51.37	50.68	50.00	49.34	48.70	48.08	47.47
8	46.88	46.30	45.74	45.18	44.64	44.12	43.60	43.10	42.61	42.13
9	41.67	41.21	40.76	40.32	39.89	39.47	39.06	38.66	38.27	37.88
10	37.50	37.13	36.77	36.41	36.06	35.71	35.38	35.05	34.72	34.40
11	34.09	33.78	33.48	33.19	32.89	32.61	32.33	32.05	31.78	31.51
12	31.25	30.99	30.74	30.49	30.24	30.00	29.76	29.53	29.30	29.07
13	28.85	28.63	28.41	28.20	27.99	27.78	27.57	27.37	27.17	26.98
14	26.79	26.60	26.41	26.22	26.04	25.86	25.68	25.51	25.34	25.17
15	25.00	24.83	24.67	24.51	24.35	24.19	24.04	23.88	23.73	23.58
16	23.44	23.29	23.15	23.01	22.87	22.73	22.59	22.46	22.32	22.19
17	22.06	21.93	21.80	21.68	21.55	21.43	21.31	21.19	21.07	20.95
18	20.83	20.72	20.60	20.49	20.38	20.27	20.16	20.05	19.95	19.84
19	19.74	19.63	19.53	19.43	19.33	19.23	19.13	19.03	18.94	18.84
20	18.75	18.66	18.56	18.47	18.38	18.29	18.20	18.12	18.03	17.94
21	17.86	17.77	17.69	17.61	17.52	17.44	17.36	17.28	17.20	17.12
22	17.05	16.97	16.89	16.82	16.74	16.67	16.59	16.52	16.45	16.37
23	16.30	16.23	16.16	16.09	16.03	15.96	15.89	15.82	15.76	15.69
24	15.63	15.56	15.50	15.43	15.37	15.31	15.24	15.18	15.12	15.06
25	15.00	14.94	14.88	14.82	14.76	14.71	14.65	14.59	14.53	14.48
26	14.42	14.37	14.31	14.26	14.20	14.15	14.10	14.04	13.99	13.94
27	13.89	13.84	13.79	13.74	13.68	13.63	13.59	13.54	13.49	13.44
28	13.39	13.35	13.30	13.25	13.20	13.16	13.11	13.07	13.02	12.98
29	12.93	12.89	12.84	12.80	12.76	12.71	12.67	12.63	12.58	12.54
30	12.50	12.46	12.42	12.38	12.34	12.30	12.26	12.22	12.18	12.14
31	12.10	12.06	12.02	11.98	11.94	11.90	11.87	11.83	11.79	11.76
32	11.72	11.68	11.65	11.61	11.57	11.54	11.50	11.47	11.43	11.40
33	11.36	11.33	11.30	11.26	11.23	11.19	11.16	11.13	11.09	11.06
34	11.03	11.00	10.96	10.93	10.90	10.87	10.84	10.81	10.78	10.74
35	10.71	10.68	10.65	10.62	10.59	10.56	10.53	10.50	10.47	10.44
36	10.42	10.39	10.36	10.33	10.30	10.27	10.24	10.21	10.18	10.16

Note:– For intermediate velocities, values per horse-power can be found by interpolation



(11)

Loco. Series. Ire 14 sheets. Sheet No. 13.

OFFICE OF GENERAL MANAGER – BALTIMORE, MD H. & O. R. R.

Loco. Series, 1r 14 sheets, Sheet No. 14.

LOCOMOTIVE RESISTANCES

(A) Cylinder to Rim of Drivers:-
Total Pounds $R = 18.7\,T + 80\,N$
in which:-
T = Tons Weight on Drivers
N = Number of Driving Axles

(B) Engine and Tender Trucks:-
Total Pounds $R = 2.6\,T + 20\,N$
in which:-
T = Tons Weight on Engine & Tender Trucks.
N = Number of Truck Axles

(C) Head End or "Air" Resistance:-
$R = 0.002\,V^2A$
in which:-
V = Velocity in Miles per Hour
A = Area (Average for Locomotive = 125 sq. Ft.)
then: assuming 125 sq. ft. as A, the formula becomes:-
Total Pounds $R = 0.25\,V^2$

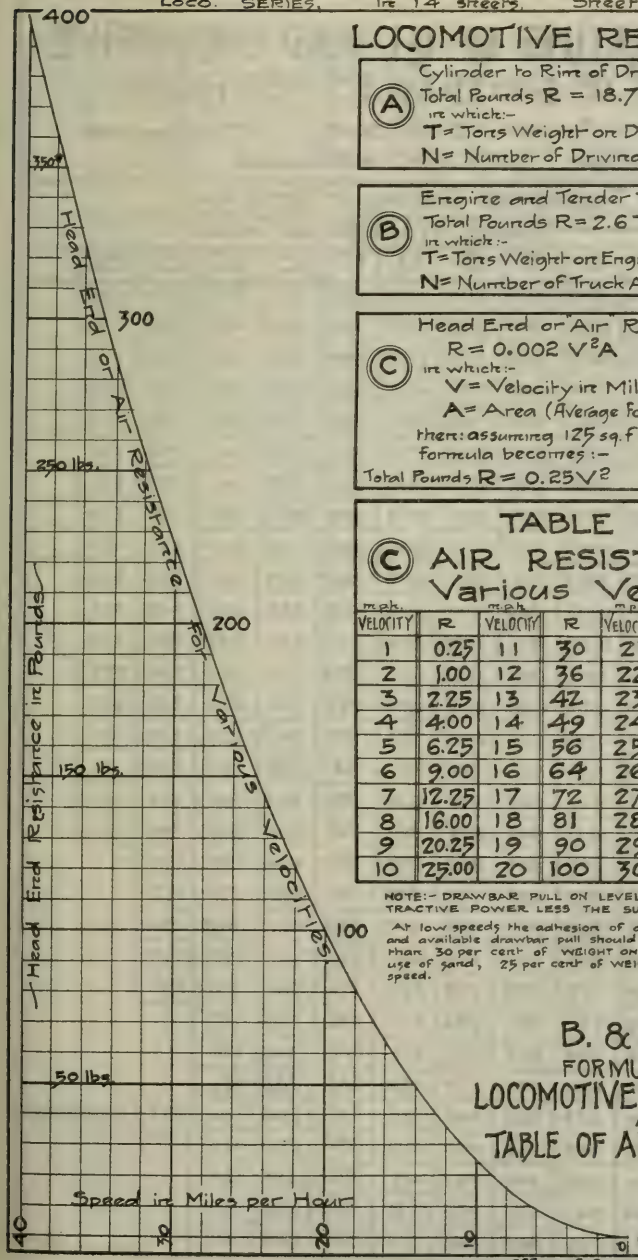


TABLE VII.

(C) AIR RESISTANCE for Various Velocities

m.p.h. VELOCITY	R	m.p.h. VELOCITY	R	m.p.h. VELOCITY	R	m.p.h. VELOCITY	R
1	0.25	11	30	21	110	31	240
2	1.00	12	36	22	121	32	256
3	2.25	13	42	23	132	33	272
4	4.00	14	49	24	144	34	289
5	6.25	15	56	25	156	35	306
6	9.00	16	64	26	169	36	324
7	12.25	17	72	27	182	37	342
8	16.00	18	81	28	196	38	361
9	20.25	19	90	29	210	39	380
10	25.00	20	100	30	225	40	400

NOTE:- DRAWBAR PULL ON LEVEL TANGENT = CYLINDER TRACTIVE POWER LESS THE SUM OF ENGINE RESISTANCES.

At low speeds the adhesion of drivers should be considered and available drawbar pull should never be estimated greater than 30 per cent of WEIGHT ON DRIVERS at starting with use of sand, 25 per cent of WEIGHT ON DRIVERS at running speed.

B. & O. R. R.
FORMULAE FOR
LOCOMOTIVE RESISTANCES
AND
TABLE OF AIR RESISTANCE

(14)

H.H.H.

Office of General Manager - Baltimore - Md.

TONNAGE RATING OF Q-1 ROAD LOCOMOTIVE
SPEEDS OF 5 TO 35 MILES PER HOUR.

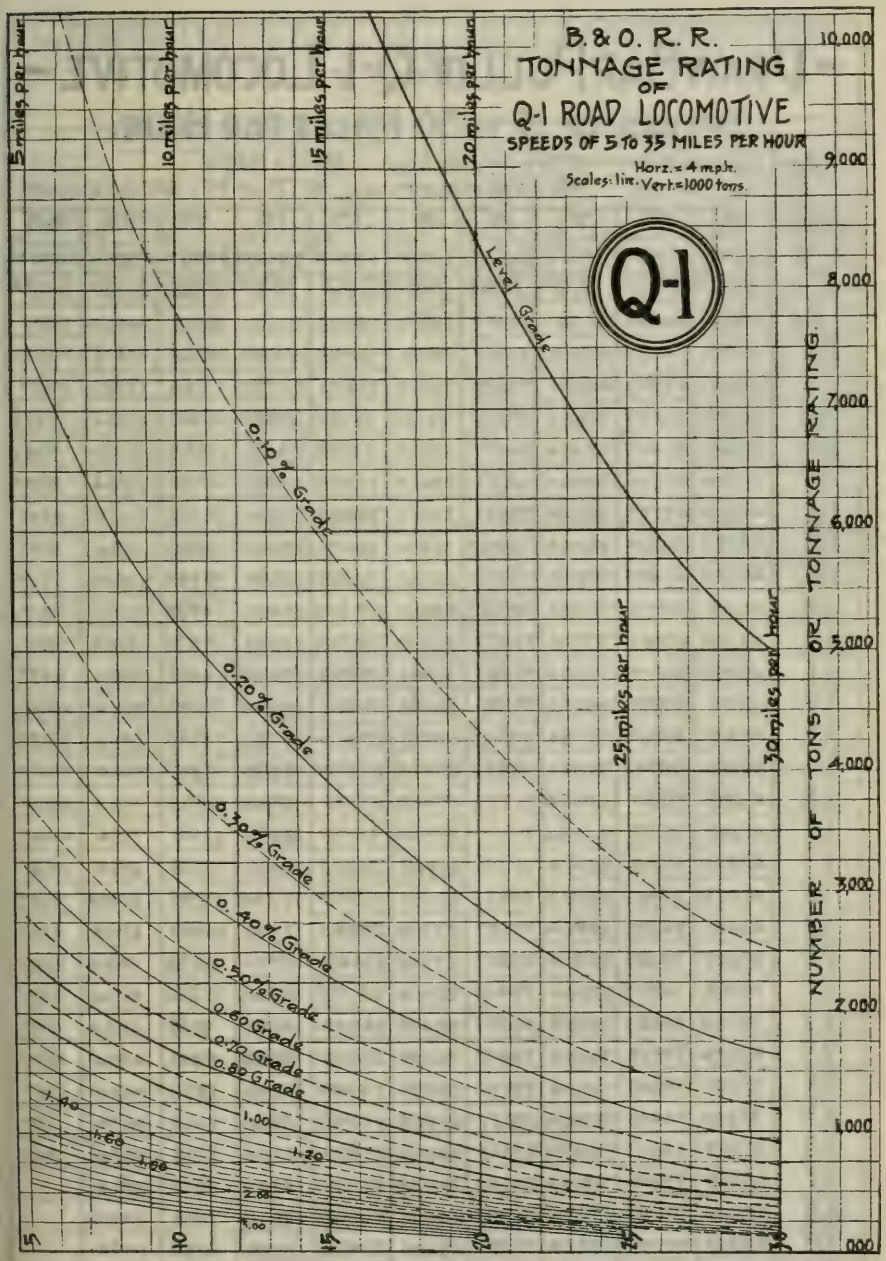
Coal Consumption = 4000* per hour B.T.U. = 13000. B.P. = 205 pounds.

"M" = 5.288 miles per hour C.T.P. at "M" = 50300 pounds.

Grade %	Adjustment in Tons per Car.				Theoretical Rating in Tons — Speed in Miles per Hour.									
	A	B	C	D	5	6	7	8	9	10	15	20	25	30
0.0	54	81	108	135	21534	20127	18520	17152	15999	15016	11311	8414	6254	4958
0.1	29	44	59	74	11231	10491	9645	8926	8319	7803	5853	4329	3193	2511
0.2	20	30	40	50	7554	7052	6478	5990	5578	5229	3905	2871	2100	1638
0.3	15	22	30	37	5666	5286	4852	4483	4173	3907	2905	2123	1539	1189
0.4	12	18	24	30	4517	4212	3862	3565	3315	3092	2296	1667	1198	917
0.5	10	15	20	25	3744	3489	3197	2948	2739	2561	1887	1361	968	733
0.6	8.5	13	18	22	3187	2969	2718	2505	2325	2172	1593	1141	803	601
0.7	7.5	12	16	20	2770	2578	2358	2171	2013	1878	1371	975	679	502
0.8	6.7	11	14	18	2444	2272	2077	1910	1769	1650	1198	845	582	424
0.9	6.0	9	12	15	2182	2027	1851	1701	1574	1467	1059	741	504	362
1.0	5.4	8	10	13	1967	1826	1666	1529	1414	1316	946	656	440	311
1.1	5.0	8	10	13	1788	1659	1511	1386	1280	1191	851	585	387	268
1.2	4.6	8	10	13	1636	1517	1380	1265	1167	1084	770	525	342	232
1.3	4.3	6	8	10	1505	1394	1268	1160	1070	993	701	473	303	201
1.4	4.0	6	8	10	1392	1289	1171	1070	985	910	641	428	269	174
1.5	3.7	6	8	10	1293	1196	1085	991	911	844	588	389	240	151
1.6	3.5	6	8	10	1205	1114	1010	921	846	783	542	354	214	130
1.7	3.3	5	6	8	1127	1041	943	859	788	728	501	323	191	111
1.8	3.1	5	6	8	1058	976	883	803	736	680	464	296	170	
1.9	2.9	5	6	8	995	917	828	753	689	635	431	271	152	
2.0	2.8	5	6	8	938	864	780	708	647	595	401	248	135	
2.1	2.7	5	6	8	886	816	735	666	608	559	373	228	119	
2.2	2.6	5	6	8	839	772	694	629	573	526	348	209	105	
2.3	2.4	3	3	5	796	731	657	594	541	496	325	192		
2.4	2.3	3	3	5	756	694	623	562	511	466	304	176		
2.5	2.2	3	3	5	719	659	591	533	484	442	285	161		
2.6	2.1	3	3	5	685	627	562	506	458	419	266	148		
2.7	2.0	3	3	5	653	598	534	480	435	396	250	135		
2.8	1.9	3	3	5	624	570	509	457	413	376	234	124		
2.9	1.8	3	3	5	596	545	485	435	392	356	220	113		
3.0	1.8	3	3	5	571	520	463	414	373	338	206	102		

OFFICE OF GENERAL MANAGER
BALTIMORE - MD.

H.E.H


B. & O. R. R.
TONNAGE RATING
OF
Q-1 ROAD LOCOMOTIVE
SPEEDS OF 5 TO 35 MILES PER HOUR
Horz. = 4 m.p.h.
Scales: Hor. Vert. = 1000 tons.
Q-1
5 miles per hour
10 miles per hour
15 miles per hour
20 miles per hour
25 miles per hour
30 miles per hour
Level Grade
0.10 % Grade
0.20 % Grade
0.30 % Grade
0.40 % Grade
0.50 % Grade
0.60 Grade
0.70 Grade
0.80 Grade
1.00
1.20
1.40
1.60
1.80
2.00
3.00
NUMBER OF TONS OR TONNAGE RATING.
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
000
5
10
15
20
25
30

— DRAW BAR PULL OF Q-1 LOCOMOTIVE —

SPEEDS OF 5 TO 30 MILES PER HOUR.

Coal Consumption = 4000 pounds per hour. B.T.U. = 13000.
B.P. = 205 pounds. "M" = 5.288 miles per hour. C.T.P. at "M" = 50300 pounds.

SPEED	5 mi.	6 mi.	7 mi.	8 mi.	9 mi.	10 mi.	15 mi.	20 mi.	25 mi.	30 mi.
RATE	0.9455"M	1.135"M.	1.324"M	1.513"M"	1.702"M	1.891"M	2.8365"M	3.7820"M	4.7275"M	5.6730"M
OF GRADE %	100.33% C.T.P.	94.12% C.T.P.	87.05% C.T.P.	81.00% C.T.P.	75.92% C.T.P.	71.61% C.T.P.	55.30% C.T.P.	42.60% C.T.P.	33.18% C.T.P.	27.48% C.T.P.
Level	47805	44683	41114	38077	35518	33345	25110	18678	13884	11007
0.1	47395	44273	40704	37667	35108	32935	24700	18268	13474	10597
0.2	46985	43863	40294	37257	34698	32525	24290	17858	13064	10187
0.3	46575	43453	39884	36847	34298	32115	23880	17448	12654	9777
0.4	46165	43043	39474	36437	33878	31605	23470	17038	12244	9367
0.5	45755	42633	39064	36027	33468	31295	23060	16628	11834	8957
0.6	45345	42223	38654	35617	33058	30885	22650	16218	11424	8547
0.7	44935	41813	38244	35207	32648	30475	22240	15808	11014	8137
0.8	44525	41403	37834	34797	32238	30065	21830	15398	10604	7727
0.9	44115	40993	37424	34387	31828	29655	21420	14988	10194	7317
1.0	43705	40583	37014	33977	31418	29245	21010	14578	9784	6907
1.1	43295	40173	36604	33567	31008	28835	20600	14168	9374	6497
1.2	42885	39763	36194	33157	30598	28425	20190	13758	8964	6087
1.3	42475	39353	35784	32747	30188	28015	19780	13348	8554	5677
1.4	42065	38943	35374	32337	29778	27505	19370	12938	8144	5267
1.5	41655	38533	34964	31927	29368	27195	18960	12528	7734	4857
1.6	41245	38123	34554	31517	28958	26785	18550	12118	7324	4447
1.7	40835	37713	34144	31107	28548	26375	18140	11708	6914	4037
1.8	40425	37303	33734	30697	28138	25965	17730	11298	6504	3627
1.9	40015	36893	33324	30287	27728	25555	17320	10888	6094	3217
2.0	39605	36483	32914	29877	27318	25145	16910	10478	5684	2807
2.1	39195	36073	32504	29467	26908	24735	16500	10068	5274	2397
2.2	38785	35663	32094	29057	26498	24325	16090	9658	4864	1987
2.3	38375	35253	31684	28647	26088	23915	15680	9248	4454	1577
2.4	37965	34843	31274	28237	25678	23405	15270	8838	4044	1167
2.5	37555	34433	30864	27827	25268	23095	14860	8428	3634	757
2.6	37145	34023	30454	27417	24858	22685	14450	8018	3224	347
2.7	36735	33613	30044	27007	24448	22275	14040	7608	2814	
2.8	36325	33203	29634	26597	24038	21865	13630	7198	2404	
2.9	35915	32793	29224	26187	23628	21455	13220	6788	1994	
3.0	35505	32383	28814	25777	23218	21045	12810	6378	1584	

Characteristics of Q-1 Locomotive
(Mikado Type)

ITEMS.	Dimens. etc
Drivers	64"
Cylinders	24"x32"
Boiler Pressure	205*
Grate Area	70 sq. ft.
Heating Surface	5014 sq. ft.
Weight on Drivers 215,000*=	107.5 tons
Weight on Trucks 55,000*=	22.5 "
Weight on Tender	70 "
Ratio Grate Area to Heating Surface	1 to 71.6
Coal consumption - pounds per hour	4000
Coal consumption per sq. ft. of G.A.	57.2*
Hourly Evaporation per sq. ft. of H.S.	5.422*
B.T.U. - Per pound of Coal	13,000
Hourly steam production	27186*
Steam production per minute	453.1*
Steam consumption per revolution	16.32*
"M" in revolutions per minute	27.76
Constant for m.p.h.	5.25
"M" in miles per hour	5.288
Steam Consumption per I.H.P. hour; full cut-off	38.181*
Resistance Cylinder to Rim of Drivers	2330*
Resistance Engine & Tender Trucks	320*
Total, not including Head End Resistance	2650*
Total weight of Locomotive and Tender	205 tons

Items	Dimensions, etc		
I.H.P. of loco. at "M" m.p.h.	709.4		
C.T.P. at "M" m.p.h.	50300*		
C.T.P.	Veloc. in "M"	% C.T.P.	Pounds
C.T.P. at 5 m.p.h	0.9455	100.33	50466
" 6 "	1.135	94.12	47342
" 7 "	1.324	87.03	43776
" 8 "	1.513	81.00	40743
" 9 "	1.702	75.92	38188
" 10 "	1.891	71.61	36020
" 15 "	2.8365	55.30	27816
" 20 "	3.7820	42.60	21428
" 25 "	4.7275	33.18	16690
" 30 "	5.6730	27.48	13822

Head End Resistance

m.p.h.	5	6	7	8	9	10	15	20	25	30
pounds	6	9	12	16	20	25	56	100	156	225

REPORT OF COMMITTEE VII—ON WOODEN BRIDGES AND TRESTLES.

I. L. SIMMONS, *Chairman;* — W. S. BOUTON, *Vice-Chairman;*
H. AUSTILL, JR. — HENRY S. JACOBY.
F. E. BISSELL. — P. B. MOTLEY.
R. D. COOMBS, — D. W. SMITH.
E. A. FRINK. — W. F. STEFFENS,
E. A. HADLEY. — H. B. STUART.
HANS IBSEN. — *Committee.*

To the Members of the American Railway Engineering Association:

Your Committee on Wooden Bridges and Trestles respectfully submits herewith its report:

The Association directed that the outline of committee work for the year 1912 be as follows:

(1) Report on formulæ for use in determining the strength of sheet piling.

(2) Report on fire protection of wooden bridges and trestles.

(3) Complete report on the use of guard-rails for wooden bridges trestles.

The Committee was divided into sub-committees and a different topic assigned to each. The work during the forepart of the year consisted of the collection and tabulation of data.

A meeting was held in Chicago on the second of November, 1912, at which were present Messrs. I. L. Simmons, Chairman; W. S. Bouton, Vice-Chairman; E. A. Frink, Hans Ibsen, D. W. Smith and H. B. Stuart. The different sub-committees furnished the information which they had collected. The points contained in the information were discussed and the Committee desires to make the following report and recommendations:

On subject (1) the Committee reports progress.

On subject (2), Report on Fire Protection of Wooden Bridges and Trestles, the Committee does not deem it advisable to make any recommendations, but submits its report as information.

On subject (3) the Committee makes the following recommendations:

CONCLUSIONS.

(1) It is recommended as good practice to use guard timbers on all open-floor bridges, and same should be so constructed as to properly space the ties and hold them securely in their places.

(2) It is recommended as good practice to use guard-rails to extend beyond the ends of the bridges for such a distance as required by local conditions, but that this length in any case be not less than fifty feet; that guard-rails be fully spiked to every tie and spliced at every joint, the guard-rail to be some form of a metal guard-rail.

(3) It is recommended that the guard timber and guard-rail be so spaced in reference to the track rail that a derailed truck will strike the guard-rail without striking the guard timber.

(4) The height of the guard-rail to be not over one inch less than the running rail.

During the year a communication was received from Mr. Lindsay, suggesting the substitution of the term "guide-rail" for "guard-rail," and after due consideration by the Committee, it was decided not to recommend the change.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

Your Committee recommends that the following subjects be assigned for the ensuing year:

(1) Complete report on formulæ for use in determining the strength of sheet piling.

(2) Report on the subject of docks and wharves.

Respectfully submitted,

COMMITTEE ON WOODEN BRIDGES AND TRESTLES.

PRACTICE OF VARIOUS RAILWAYS AS TO GUARD-RAILS.

Number	Railroad	QUESTION 1 Do you use Guard Rails on all your bridges to guide derailed car wheels?	QUESTION 2 What form of Guard Rails do you use? (a) On movable bridges. (b) On through bridges. (c) On deck bridges. (d) On timber trestles.	QUESTION 3 Do you use timber or metal Guard Rails? Give distance of guard rail from running rail.	
				Style	Distance
1	Missouri Pac.	No. See Remarks.	None	None	
2	T. & O. C.	No. See Remarks.	T-Rails. See Appendix A1.	Metal	10″
3	B. & O.	Yes. See Remarks.	T-Rails. See Appendix A2.	Metal	10″
4	K. C. S.	No.	None	None	
5	N. O. M. & C.	No.	None	None	
6	Western Maryland	Yes.	T-Rails.	Metal	8″
7	W. & L. E.	Yes. See Remarks.	T-Rails. See Appendices A1 and 2.	Metal	8″
8	Vandalia	Yes. See Remarks.	T-Rails. See Appendix A3.	Metal	10″
9	N. Y. C. & St. L.	Yes. See Remarks.	T-Rails.	Metal	8″
10	C. C. C. & St. L.	Yes. See Remarks.	T-Rails. See Appendix A2.	Metal	10″
11	L. E. & W.	Yes. See Remarks.	T-Rails. See Appendices A2 and 3.	Metal	10″
12	N. & W.	Yes. See Remarks.	T-Rails. See Appendix A1.	Metal	8″
13	B. R. & P.	No. See Remarks.	T-Rails. See Appendix A1.	Metal	9″
14	E. P. & S. W. System	No. See Remarks.	T-Rails.	Metal	8″
15	H. V.	No. See Remarks.	T-Rails. See Appendix A1.	Metal	10″
16	P. & R.	Yes.	T-Rails. See Appendix A3.	Metal	8″
17	S. P. & S.	No.	(a) Angles (d) T-Rails. (b and c) Angles or T-Rails.	Metal	
18	C. St. P. M. & O.	No. See Remarks.	T-Rails. See Appendix A1.	Metal	10″
19	Long Island	No. See Remarks.	T-Rails.	Metal	11″
20	C. N. Q.	No. See Remarks.	T-Rails.	Metal	
21	N. C. & St. L.	No. See Remarks.	T-Rails. See Appendix A9.	Metal	3½″
22	Wichita Falls	No.	None	None	
23	St. L. S. W.	No. See Remarks.	T-Rails.	Metal	8″
24	Grand Trunk	Yes.	T-Rails. See Appendix A1.	Metal	8″
25	S. F. P. & P.	No. See Remarks.	T-Rails. See Appendix A1.	Metal	8″
26	Nat. Rys. of Mexico.	No. See Remarks.	T-Rails. See Appendix A1.	Metal	8″
27	Norfolk Southern.	No. See Remarks.	T-Rails. See Appendix A1.	Metal	10″
28	Southern.	Yes.	T-Rails.	Metal	8″
29	Q. & C. Route.	Yes.	T-Rails.	Metal	10″
30	D. S. S. & A.	No.	None		
31	G. H. & S. A.	No.	None		
32	C. I. & L.	Yes. See Remarks.	T-Rails.	Metal	8″
33	P. S. & N.	Yes.	T-Rails. See Appendix A1.	Metal	8″
34	G. C. & S. F.	No. See Remarks.	T-Rails.	Metal	8″
35	Gt. Northern.	See Appendix F35.	T-Rails. See Appendices A1 and A6. Bulb Angles and Timber	Metal and Timber	
36	N. Y. O. & W.	Yes.	T-Rails. See Appendix A8.	Metal	8″
37	Maine Central.	Yes.	T-Rails.	Metal	9″
38	S. A. & A. P.	No.	None		
39	N. Y. N. H. & H.	Yes.	T-Rails.	Metal	
40	D. & H. Co.	No. See Remarks.	T-Rails.	Metal	
41	Tenn. Central.	No. See Remarks.	T-Rails.	Metal	3″
42	Lehigh Valley.	Yes.	T-Rails See Appendix A3.	Metal	8″
43	Pa. Lines West.	No. See Remarks.	T-Rails. See Appendix A3. Angle and Timber	Metal and Timber	
44	Illinois Central.	No. See Remarks.	T-Rails. See Appendix A5.	Metal	9″
45	C. M. & St. P.	Yes. See Remarks.	Angle and Timber. See Appendix A4	Metal and Timber	
46	C. & N. W.	See Appendix F46.	T-Rails. See Appendix A4. Angle and Timber	Metal and Timber	
47	B. & A.	Yes.	T-Rails—3 lines.	Metal. See Remarks.	
48	M. & St. L.	No. See Remarks.	T-Rails.	Metal	8″-9″
49	Pac. Elec.	No. See Remarks.	T-Rails. See Appendix A1.	Metal	8″
50	M. C.	Yes. See Remarks.	T-Rails. See Appendix A10.	Metal	
51	C. R. I. & P.	See Appendix F51.	T-Rails. See Appendix A1.	Metal	10″
52	C. of Ga.	No. See Remarks.	T-Rails. See Appendix A7.	Metal	8″
53	G. R. & I.	No. See Remarks.	T-Rails.	Metal	10″
54	St. J. & G. I.	No.	T-Rails. See Appendix A1.	Metal	8″
55	P. & L. E.	Yes.	T-Rails. See Appendix A11.	Metal	10″
56	C. R. R. of N. J.	Yes.	T-Rails. See Appendix A1.	Metal	8″
57	G. T. Pac.	Yes.	T-Rails. See Appendix A1.	Metal	8″
58	N. Y. C. & H. R.	Yes. See Remarks.	T-Rails. See Appendix A1.	Metal	8″
59	S. P. & U. P.	No. See Remarks.	T-Rails. See Appendix A12.	Metal	3″ & 8
60	P. I.	No. See Remarks.	T-Rails. See Appendix A13.	Metal	8″
61	C. P. R.	No. See Remarks.	T-Rails. See Appendix A14.	Metal	1′-6 1′-1½

APPENDIX A—Continued

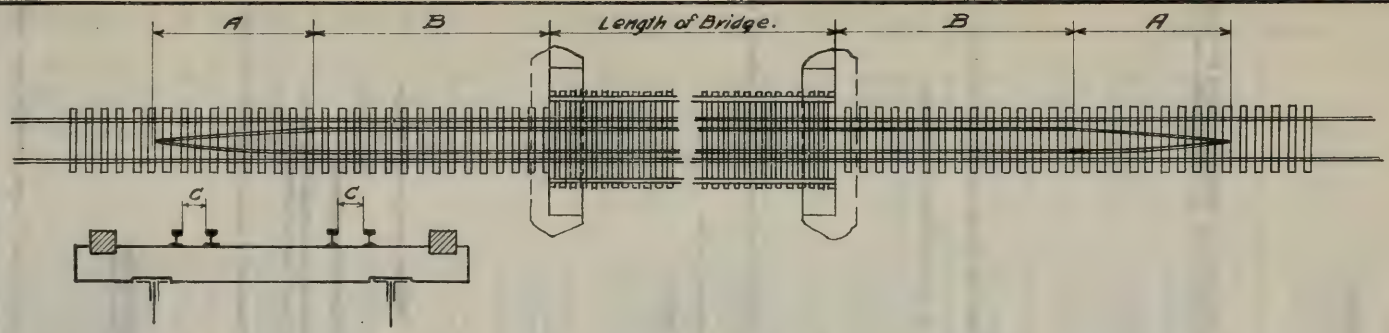
QUESTION 4 Do you use any re-railing device in connection with Guard Rails?	QUESTION 5 Please furnish specific information showing whether your re-railing device has proven effective.	QUESTION 6 How far do guard rails extend beyond ends of bridge? (a) On single track. (b) On double track.
No	No information given	No information given
No	No information given	At least 75′
No	No information given	61′
No	No information given	No information given
No	No information given	No information given
No	No information given	(a) 60′ both directions (b) 60′ Approach End
No	No information given	Generally 90′. See Appendix D7
No	No information given	100′–200′ Approach. 30′ Trailing
No	No information given	60′
No	No information given	50′
No	No information given	(a) 50′ both directions (b) 50′ Approach End
No	No information given	(a) 100′ both directions (b) 100′ Approach. 50′ Trailing
No	No information given	63′
Yes. See Appendix B14	No information given	Generally 33′
No	No information given	200′
No	No information given	Variable. See Appendix D16
No	No information given	Not stated
Used on one bridge only	No information given	28′-3″
No	No information given	(a) 30′ both directions (b) 30′ Approach. 15′ Trailing
No	No information given	6′
Yes. See Appendix B21	See Appendix C21	As little as practicable
No	No information given	No information given
No	No information given	(a) 150′ both directions (b) 15′ on trailing end
No	No information given	51′
No	No information given	60′
No	No information given	33′-4″
No	No information given	(a) 50′
No	No information given	50′ or more
No	No information given	See Remarks
No	No information given	30′ to 300′
No	No information given	50′
No	No information given	(a) 44′-6″ See Appendix D34 (b) 44′-6″ Approach. 10′ Trailing
No	No information given	90′ See Appendix D35
No	No information given	43′
No	No information given	(a) 60′ both directions (b) 60′ Approach. 8′ Trailing
No	No information given	(a) 75′ both directions (b) 75′ Approach. 0 Trailing
No	No information given	30′
No	No information given	60′ beyond end of Curve
No	No information given	(a) 60′ both directions (b) 60′ Approach. 10′ Trailing
No	No information given	See Appendix D43
Yes. See Appendix B44	See Appendix C44	About 30′
No	No information given	30′ to 120′
No	No information given	(a) 150′ both directions (b) 150′ Approach
No	No information given	50′ on tangent. On curves distance depends on conditions
No	No information given	(a) 50′ both directions (b) 50′ Approach. 10′ Trailing
No	No information given	50′
No	No information given	75′
No	No information given	See Appendix D51
No	No information given	50′. On curves over 3° at least 200′
No	No information given	200′
No	No information given	43′
Yes. See Appendix B55	See Appendix C55	About 75′
No	No information given	From 60′ to 65′
No	No information given	Variable—25′ Minimum
No	No information given	50′
Yes	No information given	(a) and (b). 50′
No	No information given	(a) and (b) 50′
No information given	No information given	No extension on deck bridge 8′ on through bridges

APPENDIX A—Continued

Number	Railroad	QUESTION 7 Please give as full information as possible of instances where the Guard Rails you use have proven efficient in service.	QUESTION 8 Please give cost per linear foot of track of guard rails used by your line.	QUESTION 9 Do you use Guard Timbers all your bridges?
1	Missouri Pac	No information given	No information given	Yes
2	T. & O. C	No information given	No information given	Yes. 4″x8″ flat
3	B. & O	No information given	No information given	Yes. 6″x8″ flat
4	K. C. S	No information given	No information given	Yes. 7″x8″
5	N. O. M. & C	No information given	No information given	Yes. 5″x8″
6	Western Maryland	No information given	Average $1.00	Yes
7	W. & L. E	No information given	No information given	Yes. 6″x8″ flat
8	Vandalia	No information given	No information given	Yes. 6″x8″ flat
9	N. Y. C. & St. L	See Appendix E9	No information given	Yes
10	C. C. C. & St. L	See Appendix E10	55c using 80 lb. Rail	Yes. 6″x8″ flat
11	L. E. & W	See Appendix E11	35c	Yes
12	N. & W	No information given	About 60c	Yes. 6″x8″ flat
13	B. R. & P	No information given	About 60c	Yes
14	E. P. & S. W. System	No information given	No record	Yes. 6″x8″ flat
15	H. V	No information given	80c	Yes
16	P. & R	No information given	$1.10	Yes. 6″x8″ flat
17	S. P. & S	No information given	75c	Yes
18	C. St. P. M. & O	No information given	No information given	Yes. 8″x8″
19	Long Island	No information given	No information given	Yes
20	C. N. Q	See Appendix E20	No information given	Yes. 8″x12″
21	N. C. & St. L	No information given	About 75c	Yes. 4″ thick
22	Wichita Falls	No information given	No information given	Yes. 6″x8″
23	St. L. S. W	No information given	No information given	Yes
24	Grand Trunk	See Appendix E24	No information given	Yes. 8″x10″
25	S. F. P. & P	See Appendix E25	About $1.60	Yes
26	Nat. Rys. of Mexico	No information given	About 50c gold	Yes. 6″x8″
27	Norfolk Southern	See Appendix E27	No information given	Yes. 8″x8″
28	Southern	No information given	No information given	Yes
29	Q. & C. Route	No information given	75c	Yes. 6″x8″ flat
30	D. S. S. & A			Yes
31	G. H. & S. A			Yes
32	C. I. & L	No information given	No information given	Yes
33	P. S. & N	No information given	No information given	Yes
34	G. C. & S. F	No information given	50c	Yes
35	Gt. Northern	No information given	Angles=$1.00×$200.00 T-Rails=50c×$92.00	Yes
36	N. Y. O. & W	No information given	No information given	Yes. 6″x8″ flat
37	Maine Central	No information given	No information given	Yes
38	S. A. & A. P			No
39	N. Y. N. H. & H	No information given	Old rails $15.00 ton	Yes, with 3″x2½″x½″L
40	D. & H. Co	No information given	Old rails $22.00 ton	Yes. 6″x8″ flat
41	Tenn. Central	No information given	40c	Yes. 6″x8″ flat
42	Lehigh Valley	See Appendix E42	No information given	Yes. 6″x8″ flat
43	Pa. Lines West	See Appendix E43	No information given	Yes. 6″x8″ flat
44	Illinois Central	No information given	70c	Yes. 6″x8″ flat
45	C. M. & St. P	See Appendix E45	About 85c	Yes. 6″x8″ flat
46	C. & N. W	See Appendix E46	$3.00 to $4.00	Yes. 4x10 Timber bridges... 10x12 Steel bridges
47	B. & A	No information given	No information given	Yes
48	M. & St. L	No information given	No information given	Yes, with 3″x3″x⅜″ Angle
49	Pac. Elec	No information given	About $1.25	Yes
50	M. C	See Appendix E50	90c and $40.00	Yes. 6″x8″ flat
51	C. R. I. & P	See Appendix E51	No information given	Yes
52	C. of Ga	See Appendix E52	About 50c	Yes
53	G. R. & I	No information given	About 50c	Yes. 6″x8″ flat
54	St. J. & G. I	No information given	No information given	Yes
55	P. & L. E	No information given	No information given	No
56	C. R. R. of N. J	See Appendix E56	About 65c	Yes. 6″x8″ flat
57	G. T. Pac	No information given	No information given	Yes. 6″x8″ flat
58	N. Y. C. & H. R	No information given	Old rails $20.00 per ton	Yes. 5″x8″ flat
59	S. P. & U. P	No information given	No information given	Yes. 5″x8″ flat
60	P. I	No information given	No information given	Yes. 6″x8″ flat
61	C. P. R	No information given	No information given	Yes. 6″x8″ flat

APPENDIX A—Continued

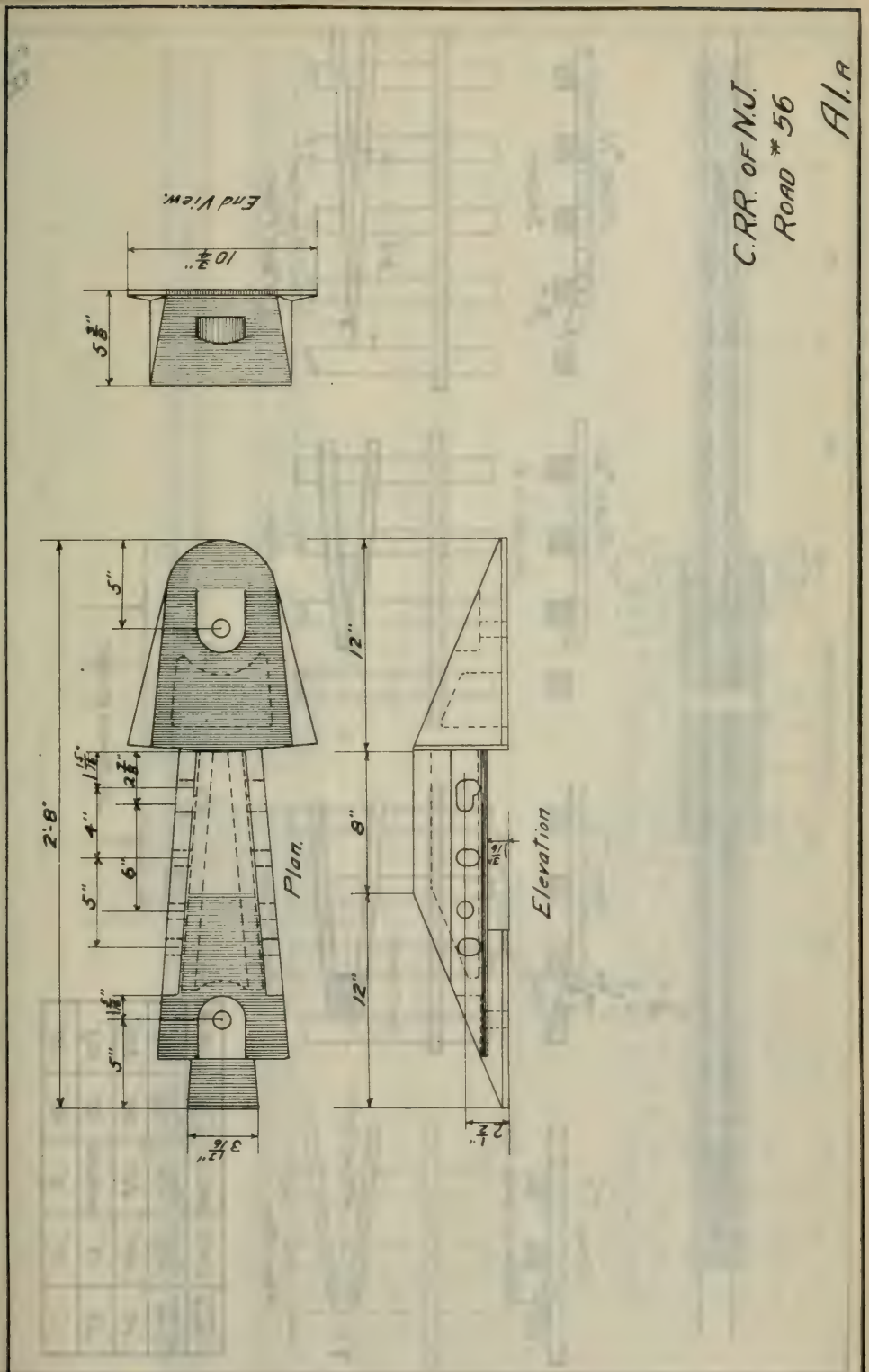
QUESTION 10 Do you notch the Guard Timber on your standard track on bridges? If so, to what depth? If not, what means do you use to maintain the spacing of ties?	REMARKS
Notched 2"	Guard Rails are on a few old bridges.
No. 3"x6" Spacer blocks	Guard Rails used on metal bridges only. They may be omitted on bridges less than 30'.
Notched 1"	Guard Rails used on all through and deck bridges with open floors, arches and ballast floor bridges on curves.
Notched 1½"	
Notched 1½"	
Notched 1"	
Notched 1"	Guard Rails used on all bridges over 90'.
Tie dapped ¾"	Open floor metal bridges only.
Guard Timber dapped ¾"	
Tie dapped ¾"	Open floor bridges over 15' only.
Guard Timber dapped ¾"	
Notched 1"	Except short deck bridges on tangent.
3" Spacer blocks	Except bridges less than 30' on tangent.
Notched 1" on Metal bridges	On all bridges 100' long or over. Special cases high bridges and bridges on curves.
Notched 1½" on Trestles	
Notched 1"	Except in special cases.
Notched 1½"	On high and long bridges only. Not used on timber ballast floor bridges.
Notched ½"	Used only where recommended.
Notched 1"	
Notched 1"	
Notched 2"	Used on many bridges, but not all.
Notched ¾" to 1"	Used on open floor bridges only.
Notched 1"	Used on high deck bridges only.
No. ¾" lag screws	Used only where derailments may occur.
Notched 1½"	
Notched 2"	Used on important bridges only. When approach is on a curve, rails are extended more than 150'.
Notched 1"	4"x4" Spacer blocks used between ties.
Notched 1½"	Used on through bridges and on timber trestles on curves.
Notched 1"	Used on permanent bridges only.
Notched 1"	Guard rails used at or near curves and on grades.
Notched 2"	
No. Each tie is bolted	Distance depends upon local conditions.
Notched 2"	
Notched 1"	
Notched. Depth not given	Used on bridges 50' or longer.
Notched 1"	
Notched 1½" to 2"	Used on through bridges only.
Notched 2"	
Notched ½"	
Notched 1"	
Notched 1"	
Notched 5" and bolted	Used on deck bridges of 50' span or more. Also on some through bridges.
Notched 1"	Used on a few bridges on curves.
Notched 1½"	
Notched ¾" and Tie ¾"	Used only on those bridges that seem to require such protection.
Notched 1"	Used on steel bridges only. Used on trestles only when high or on curves.
Notched 1". See Remarks	Except on short deck bridges. Trying out spacer blocks between ties.
4x10 spiked to every tie	
10x12 notched 1	
Notched 1"	The two outside rails are bent together beyond end of bridge to meet the center rail.
Notched 1½"	Used in a few cases only.
Notched ½". Ties ½"	Used on steel deck bridges only.
No. Bolts and drifts	Used on all bridges over 30' long.
Notched 1½"	
Notched 1"	Used only on the highest and more important bridges.
Notched 1". Tie ¾"	Used only on such bridges as are deemed hazardous.
Notched 1"	
3 blocks—3"x4"x9"	
Notched 1"	
Notched 1½"	
Notched 1"	Used on bridges 20' long or more.
Notched 1"	Used on all Truss spans, trestles or curves sharper than 12°, and all trestles longer than 150'.
Notched 1"	Used on important bridges on the approval of the Chief Engineer.
Notched 1"	Used on all deck bridges and trestles over 100' long, and all through and half through bridges 33' long or more.



Road No.	A.	B.	A & B	C.	Style of Point.
2			75 Min.	10"	Rails brought together & beveled at ends.
7	30'	30'	60'	8"	Frog Point or Rails planed to fit.
12			100'	8"	Frog Point or C.I. Point.
13	33'	30'	63'	9"	#9 Frog Point.
15	30'	170'	200'	10"	#8 Frog Point.
18	18'	10'	28'	10"	Rails brought together & planed to #6 Frg angle
24	39'	12'	51	8"	#10 Frog Point.
25	25'	35'	60'	8"	Rails brought together without fitting.
26	25½'	7½'	33'	8"	C.I. Point.
27	15'	35'	50'	10"	Frog Point.
33	45'	5'	50'	8"	#8 Frog Point.
35			24' to 90	8"	Frog Point
49	20'	30'	50'	8"	#6 Frog Point.
51	10'		60' Min.	10"	C.I. Point
54			43'	8"	C.I. Point.
56			60' to 65	8"	C.I. Point.
57	22'		25' Min.	8"	C.I. Point.
58			50' Min.	8"	Frog Point. Point beveled.

Road No.	Initials or Name.
2	T. & O.C.
7	W. & L.E.
12	N. & W.
13	B.R. & P.
15	H.V.
18	C. St. P. M. & O.
24	G.T.
25	S.F.P. & P.
26	Nat'l. Ry's. of Mexico.
27	Norfolk Southern.
33	P.S. & N.
35	Great Northern.
49	Pacific Elec.
51	C.R.I. & P.
54	St. J. & G.I.
56	C.R.R. of N.J.
57	Grand Trunk Pacific.
58	N.Y.C. & H.R.

A1.


C.R.R. OF N.J.
ROAD * 56
A1.A
End View.
10¾"
5⅜"
Plan.
2'-8"
5"
4"
6"
5"
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2⅜"
1½"
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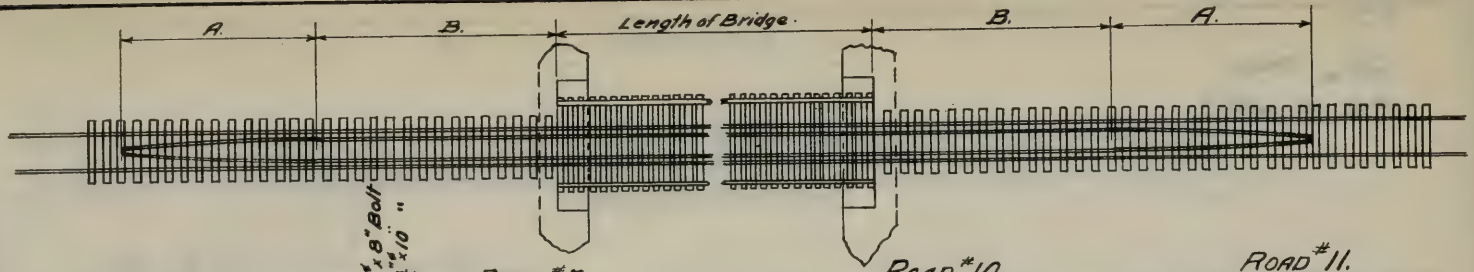
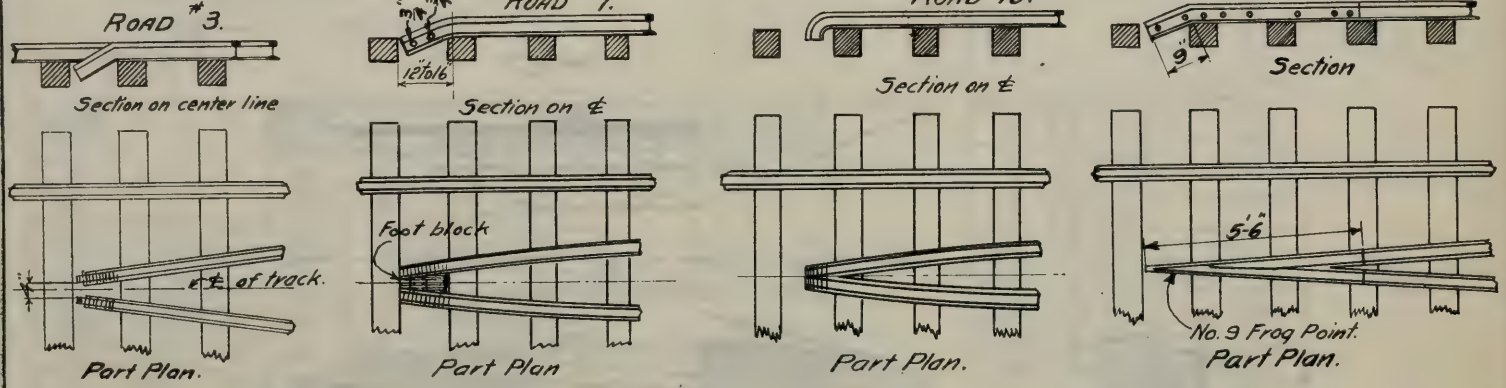
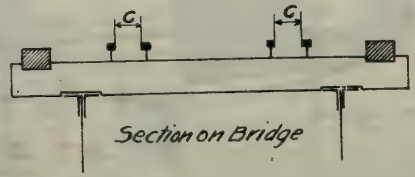
3½"
12"
Elevation
12"
8"
12"
2½"





Name of Road	B. & O.	W. & L. E.	C. C. C. & St. L.	L. E. & W.
Dimension.	Road #3	Road #7	Road #10	Road #11.
A.	48'	20'	30'	39½'
B.	13'	40' to 100	20'	10½'
C.	10"	8"	10"	10"



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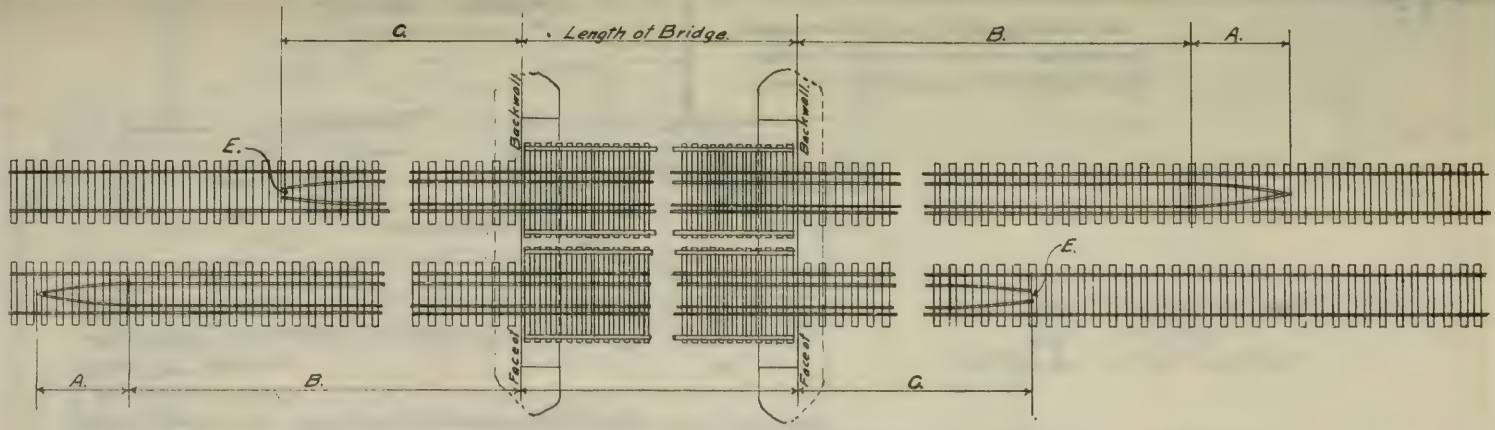
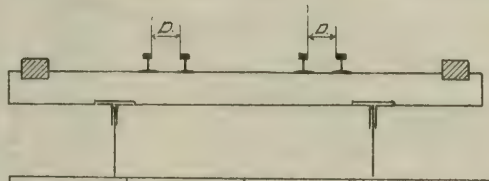
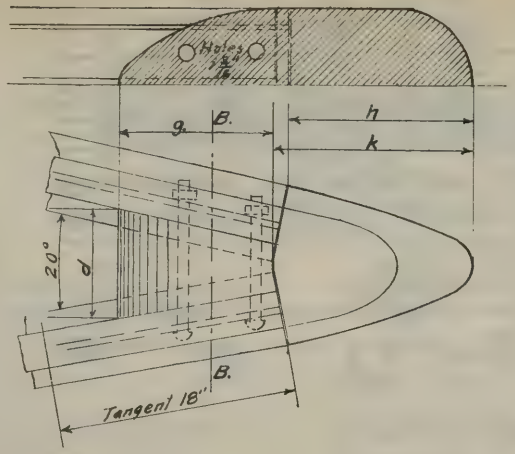
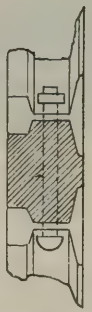




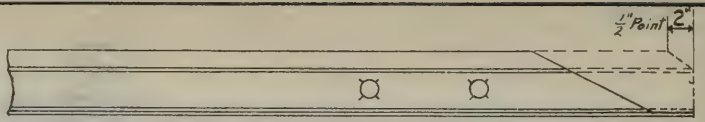
Name of Road	Vandalia	P. & R.	Lehigh Valley	Pa. Lines W.	L.E. & W.	N. & W.
Dimension	Road #8.	Road #16.	Road #42.	Road #43.	Road #11	Road #12.
A.	13'	31' to 58'	25'	14'	39½'	100'
B.	87' to 187	10'	60'	186'	10½'	
C.	30'	30'-60'	10'	30'		50'
D.	10"	8"	8"	10"	10"	8"
E.		18"	12"		2'-6"	0'-0"

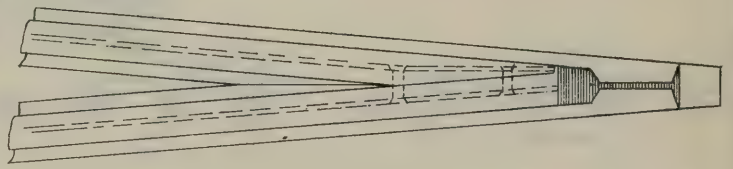
A 3





Section B.B.





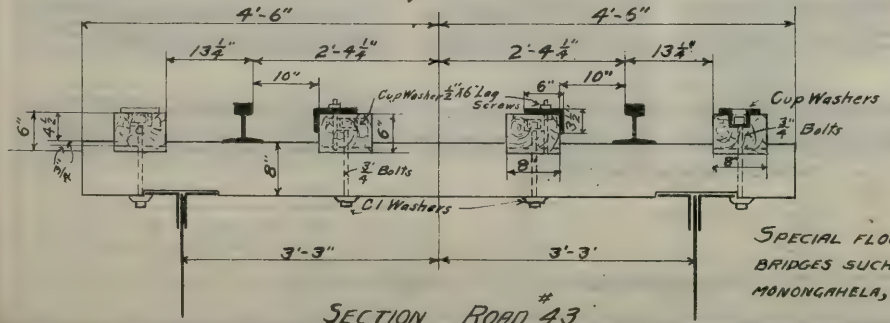
Road #16 as above N° 6, 8, 10 Frog to be used Planing not to extend back of miter & to avoid bolt holes.

Note: Dimensions indicated by letters vary with size of rail

Road #8 as above

Road #43 " " except angle is 25°, & 3 bolts.

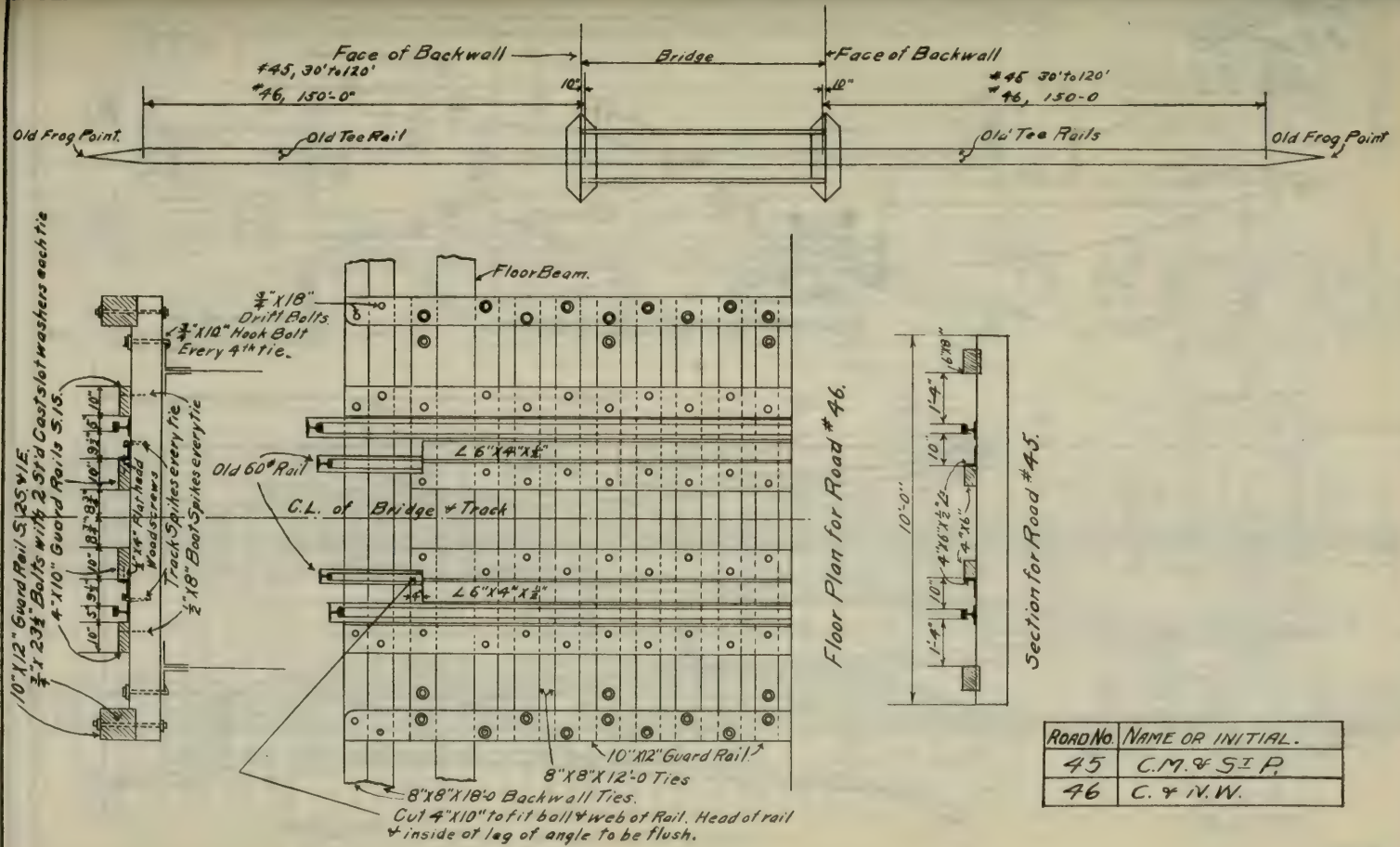
Road #8 is Vandalia Ry.
" #16 " P. & R.
" #43 " Pa. Lines West.



SECTION ROAD #43

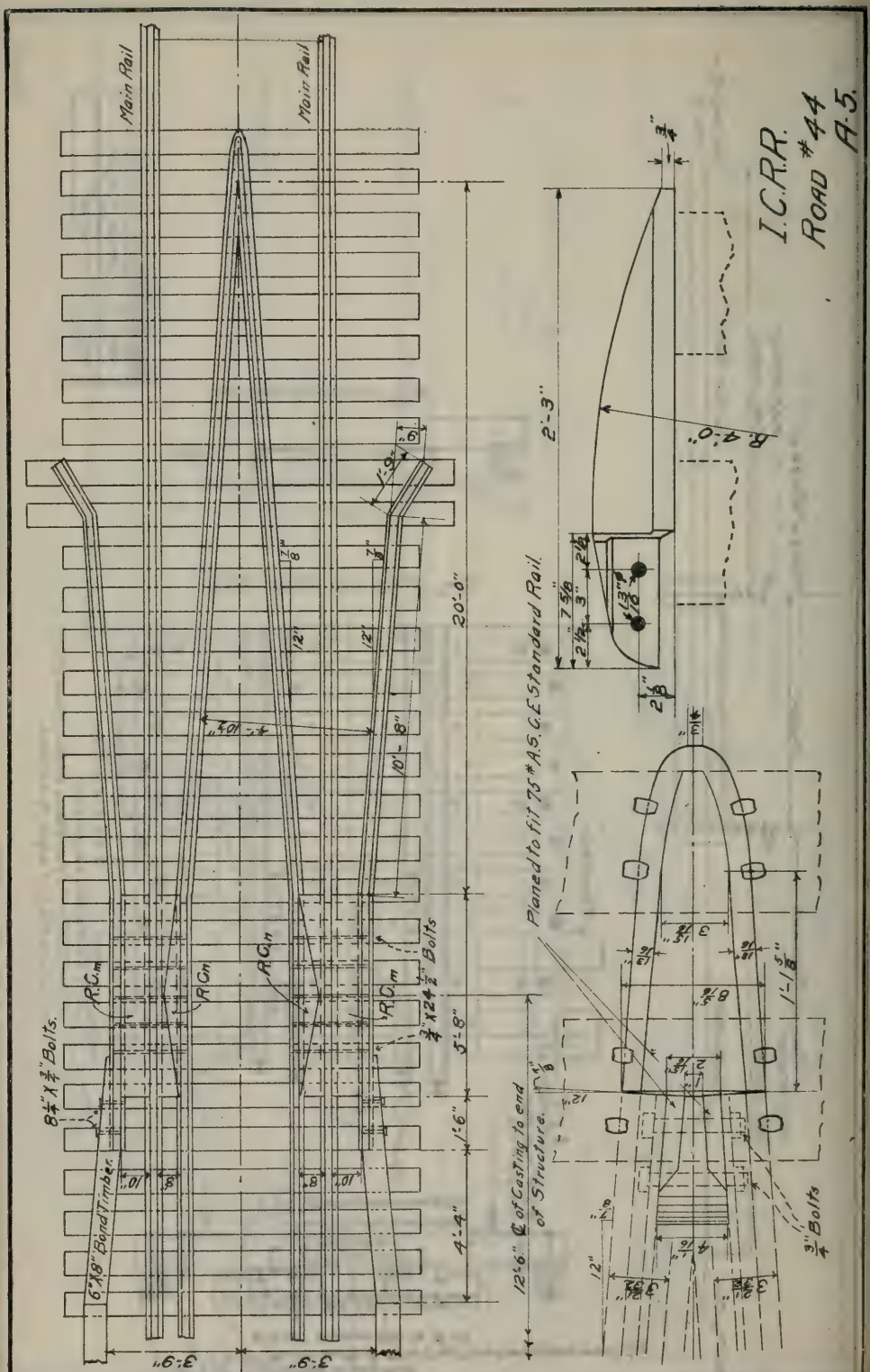
SPECIAL FLOOR DECK CONSTRUCTION FOR BRIDGES SUCH AS OVER THE ALLEGHENY, MONONGAHELA, OHIO, BEAVER RIVER ETC.

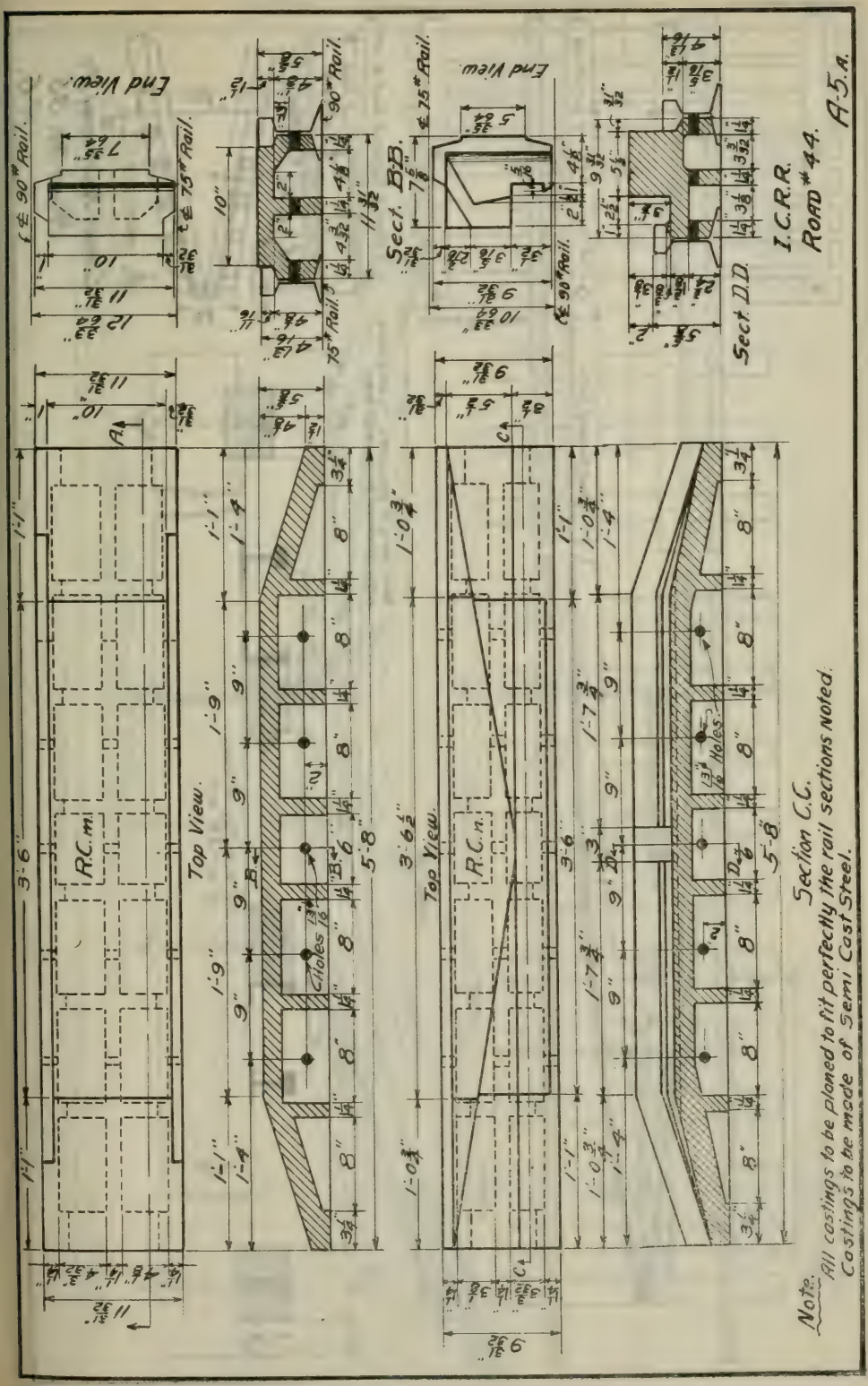
A3 a.

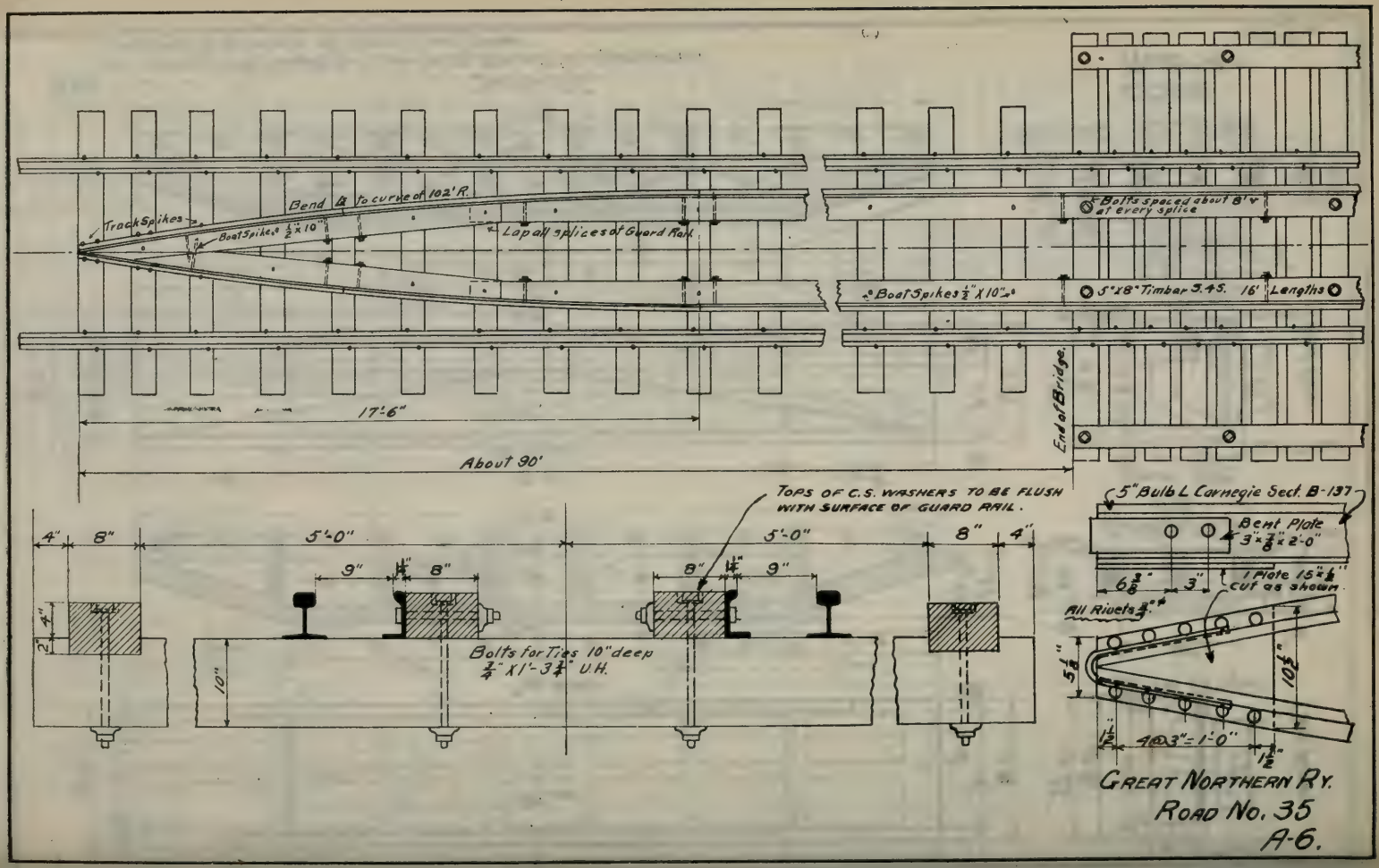


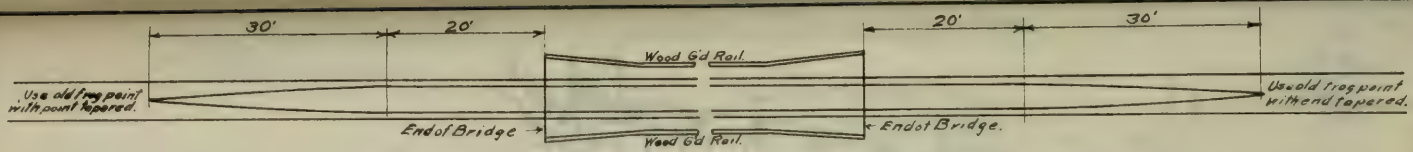
Road No.	Name or Initial.
45	C.M.& St.P.
46	C. & N.W.

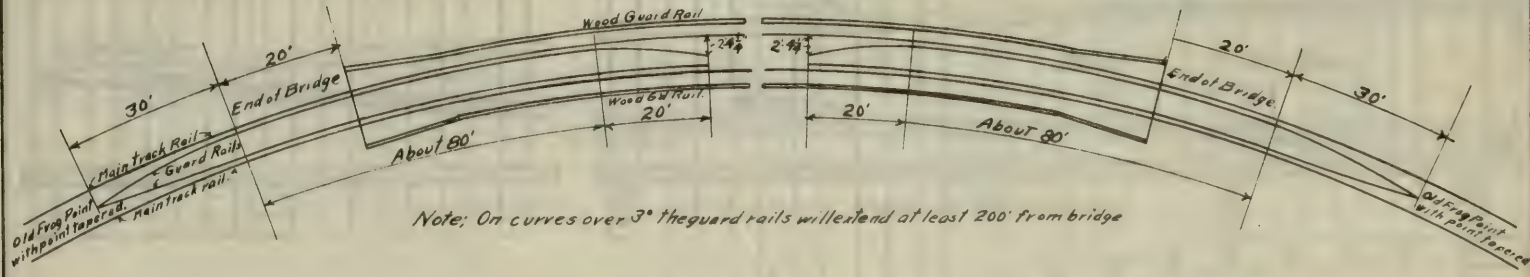
A4


I.C.R.R.
Road #44
A-5.
Main Rail
Main Rail
20'-0"
12'
12'
10'-8"
5'-8"
1'-6"
4'-4"
3'-9"
3'-9"
8 3/4" X 3/4" Bolts.
6"X8" Bond Timber.
P.C.m
A.C.m
A.C.m
A.C.m
4" X 12" 1/2" Bolts
Planed to fit 75 lb. A.S.C.E. Standard Rail.
2'-3"
R 4'-0"
12'-6" ℄ of Casting to end of Structure.
3/4" Bolts


I.C.R.R.
Road № 44.
A-5.A.
Sect. BB.
End View.
Sect. DD.
Top View.
Section C.C.
R.C.m.
Holes
Note.
All castings to be planed to fit perfectly the rail sections noted.
Castings to be made of Semi Cast Steel.


Track Spikes
Boat Spikes 1/2 x 10"
Bend to curve of 102' R.
Lap all splices of Guard Rail
17'-6"
About 90'
Bolts spaced about 8' c to c at every splice
2 Boat Spikes 1/2" X 10"
5" x 8" Timber 3.4 S. 16' Lengths
End of Bridge
TOPS OF C.S. WASHERS TO BE FLUSH WITH SURFACE OF GUARD RAIL.
4"
8"
5'-0"
9"
8"
10"
Bolts for Ties 10" deep 7/8" X 1'-3 7/8" U.H.
5" Bulb L Carnegie Sect. B-137
Bent Plate 3" x 7/8" x 2'-0"
1 Plate 15" x 1/2" cut as shown
All Rivets 7/8"
6 3/8"
3"
5 1/8"
10 1/2"
1 1/2"
4 @ 3" = 1'-0"
GREAT NORTHERN RY.
ROAD No. 35
A-6.





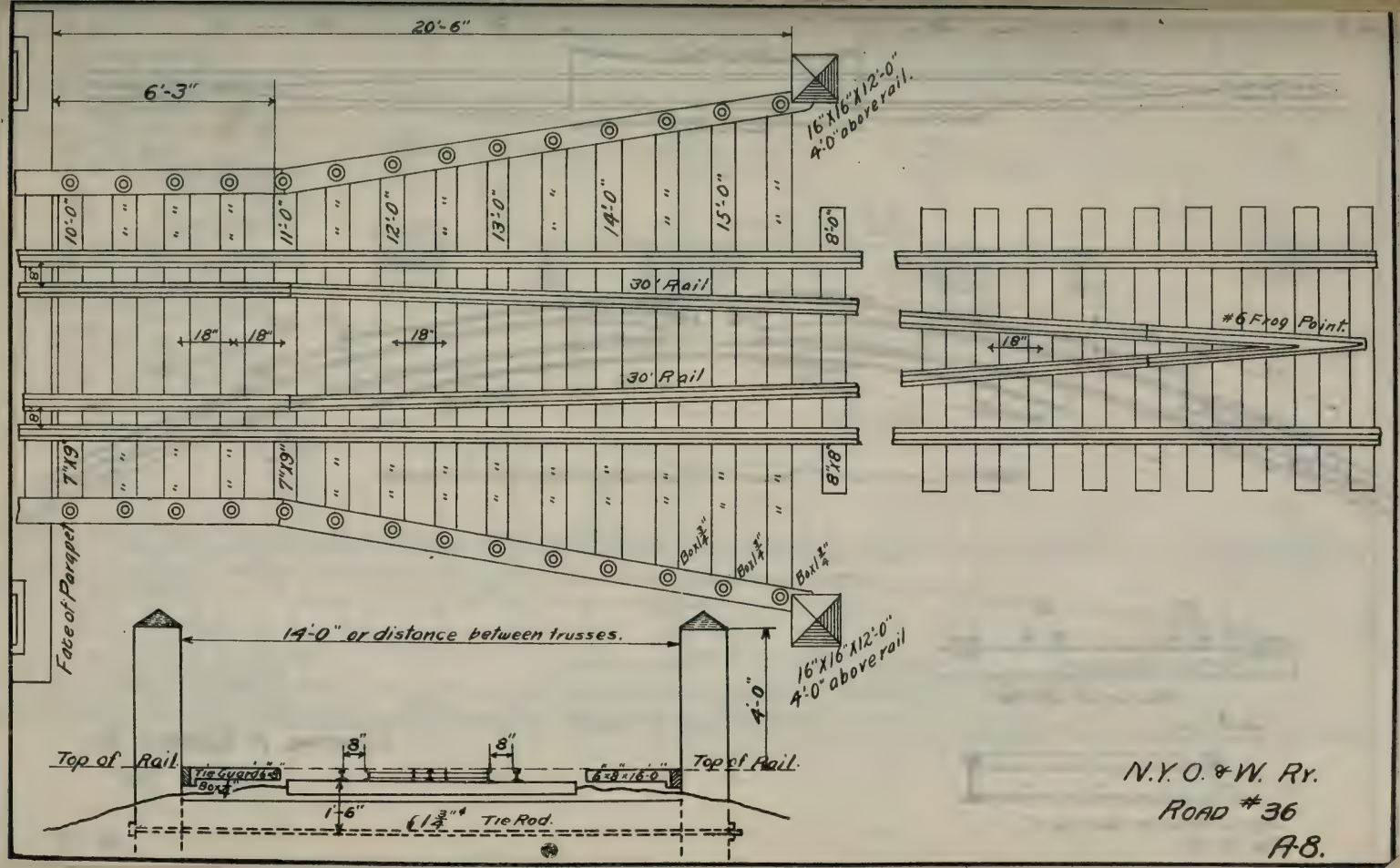
Note; On curves over 3° the guard rails will extend at least 200' from bridge

Section on Bridge.

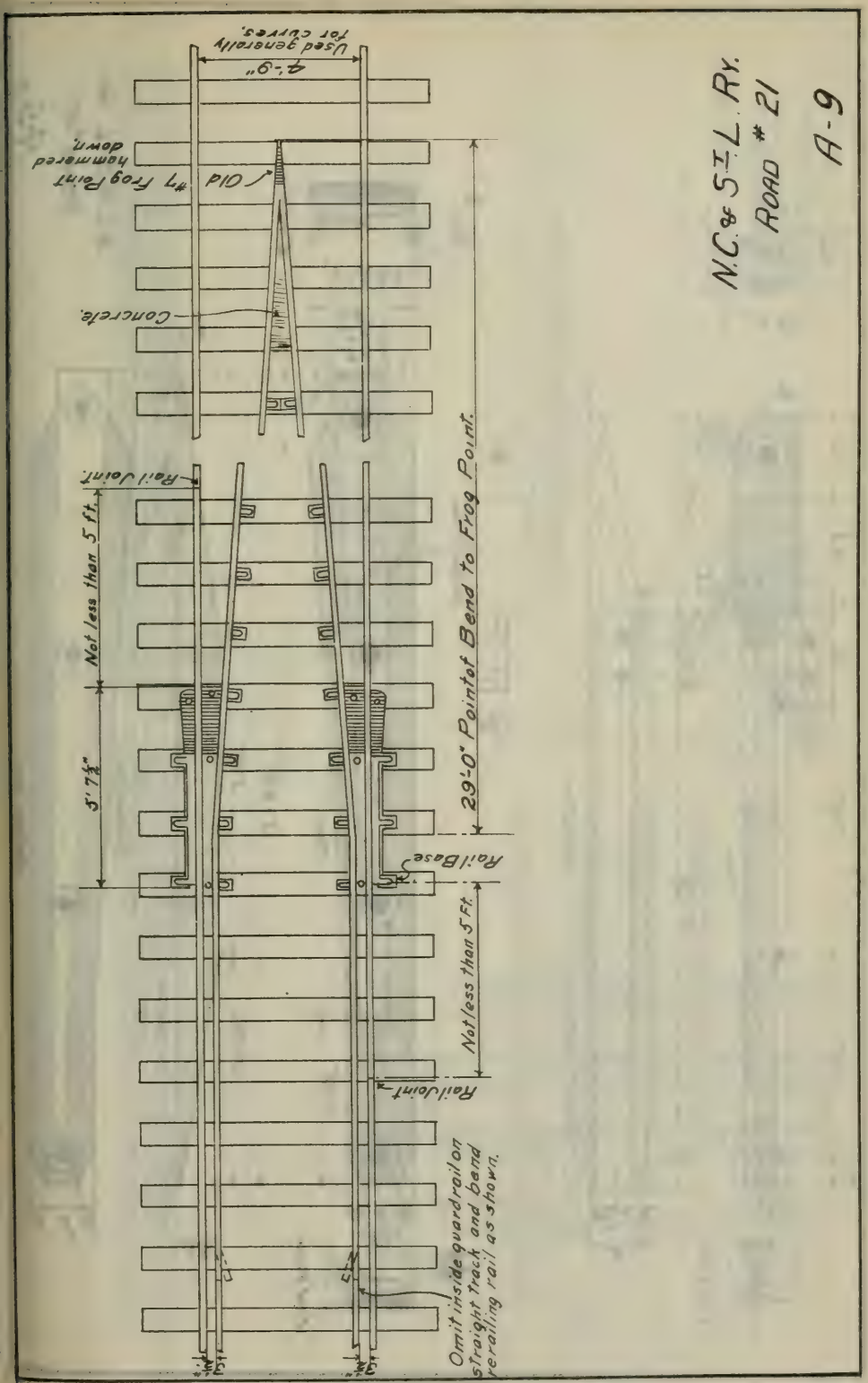
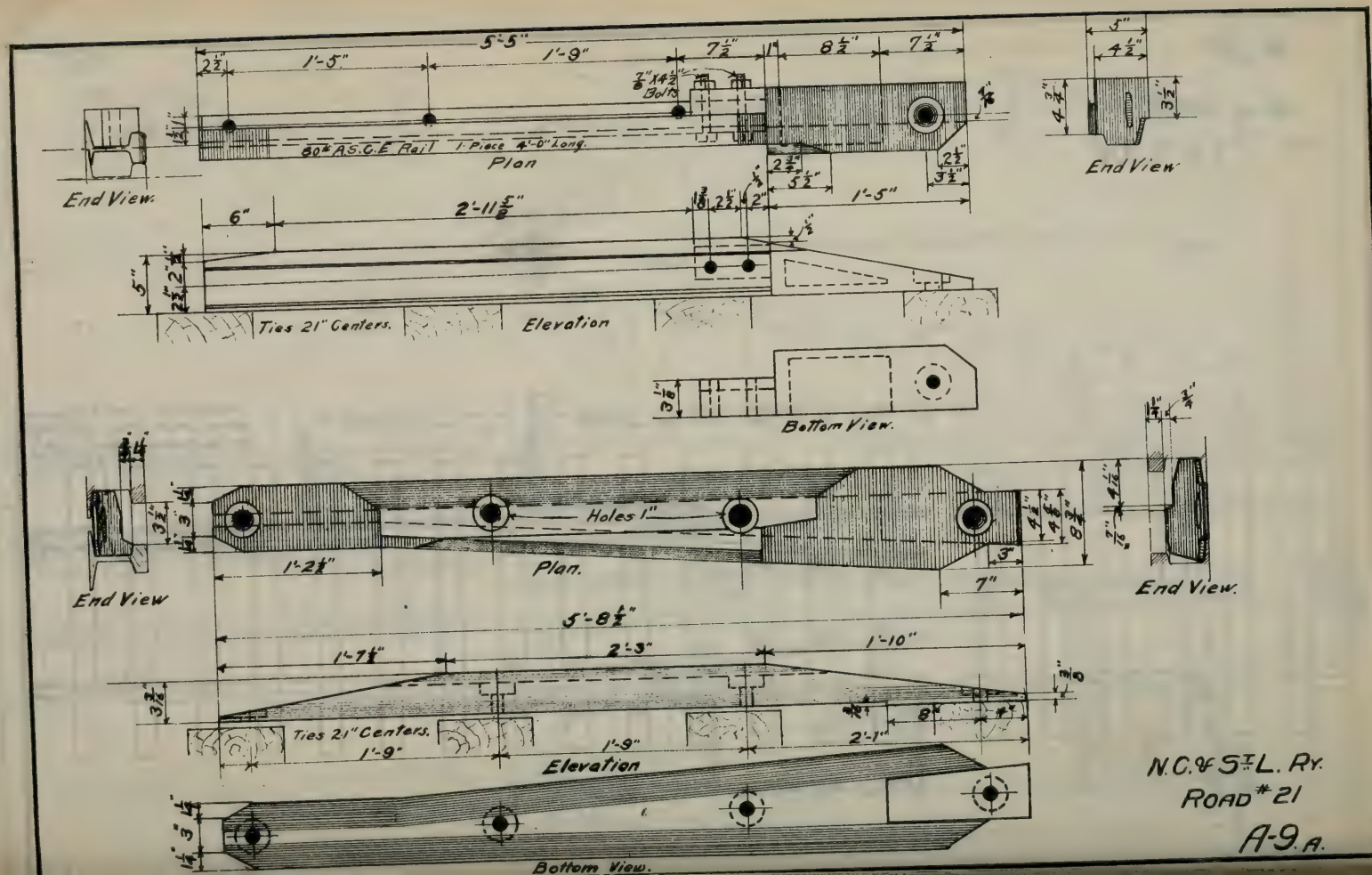
Sketch showing tapering of Frog points.

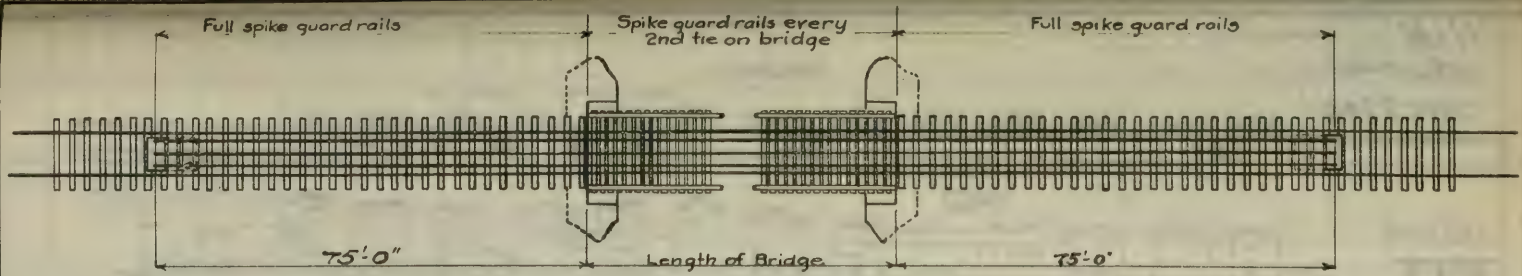
CENTRAL OF GEORGIA RY.
ROAD #52.

A-7.

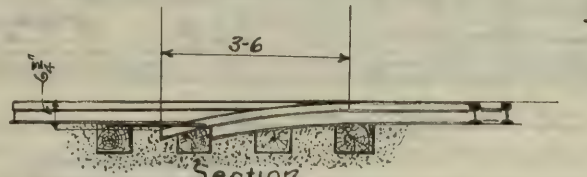


N.Y.O. & W. Ry.
ROAD #36
A-8.

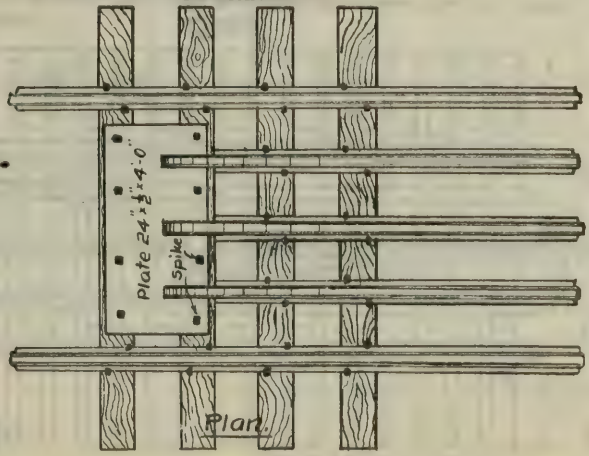

N.C. & S.-I. L. Ry.
ROAD # 21
A-9
Used generally for curves.
4'-9"
#7 Frog Point hammered down.
Old
Concrete.
Rail Joint.
Not less than 5 ft.
5'-7½"
29'-0" Point of Bend to Frog Point.
Rail Base
Not less than 5 Ft.
Rail Joint
Omit inside guard rail on straight track and bend rerailing rail as shown.

5'-5"
1'-5"
1'-9"
7½"
8½"
7½"
80# A.S.C.E. Rail 1 Piece 4'-0" Long.
Plan
End View.
End View.
2'-11⅝"
6"
5"
Ties 21" Centers.
Elevation
Bottom View.
Holes 1"
1'-2½"
Plan.
End View
End View.
5'-8½"
1'-7½"
2'-3"
1'-10"
Ties 21" Centers.
1'-9"
1'-9"
2'-1"
Elevation
Bottom View.
N.C. & St. L. Ry.
Road # 21
A-9.A.



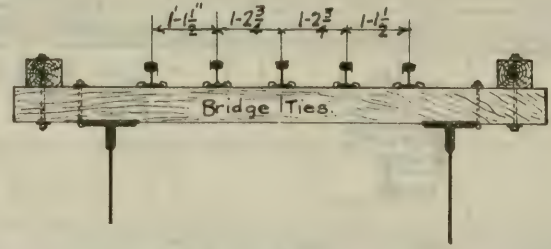
General Plan.



Section.



Plan.



Cross Section at End of Bridge.

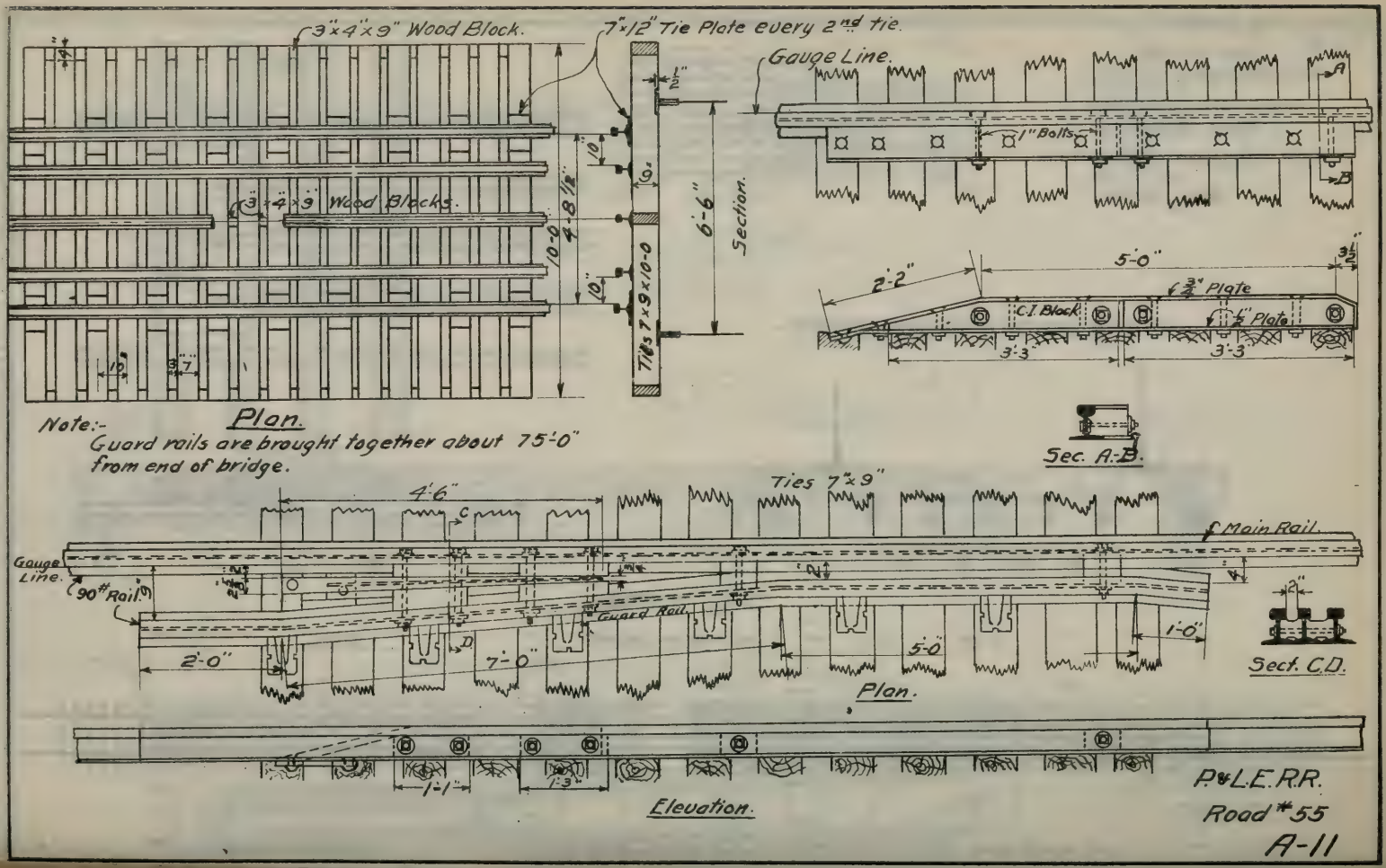
Note:
Inner Guard Rails required on all bridges exceeding 30 feet in length.
Guard Rails to be spiked every 2nd tie on bridge. Full spike on approaches.
Outer ends of Guard Rails to be bent down and fastened by plate as shown.
Splice bars to be full bolted.
Use smooth relaying Rail.

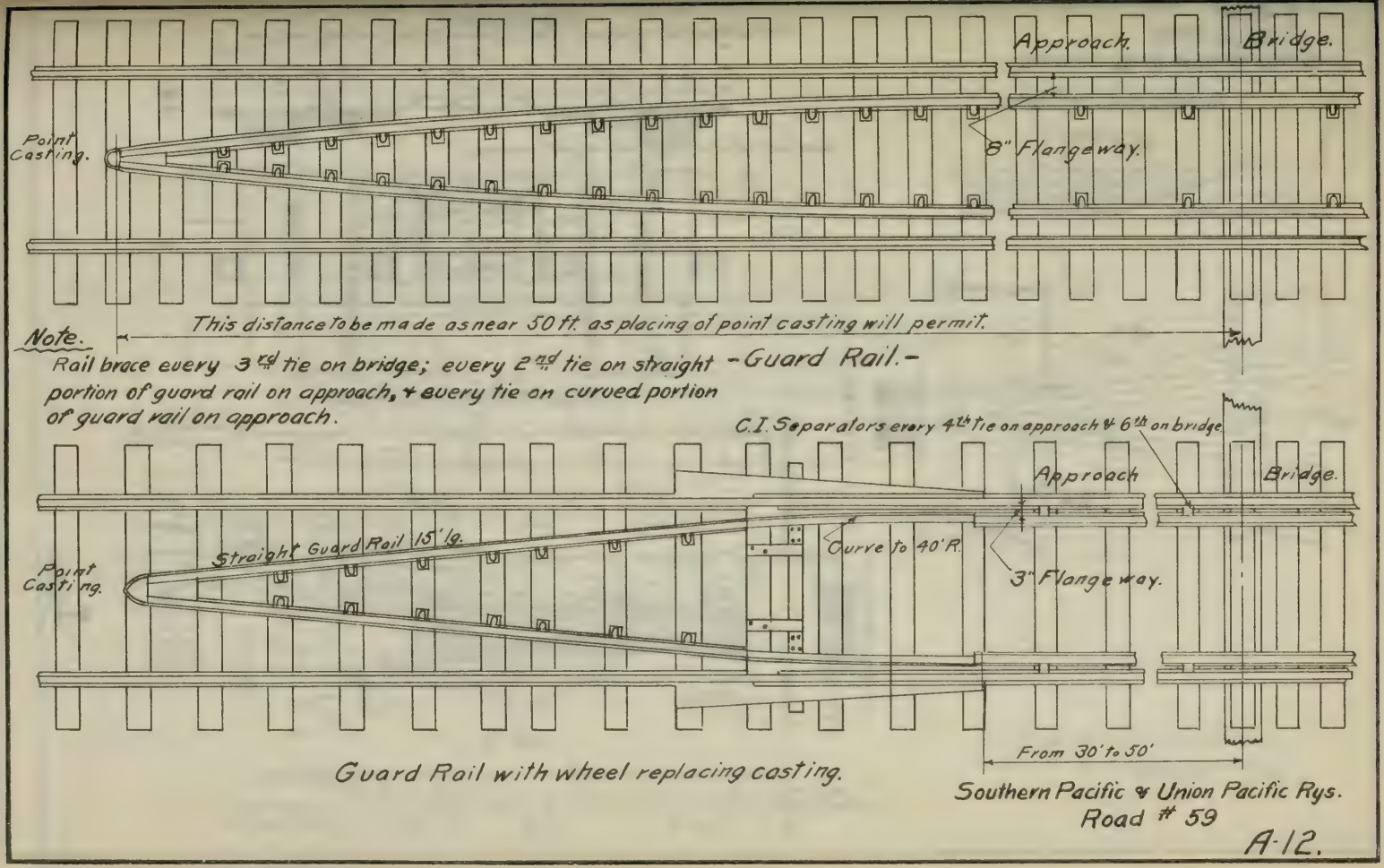
ROAD # 50.

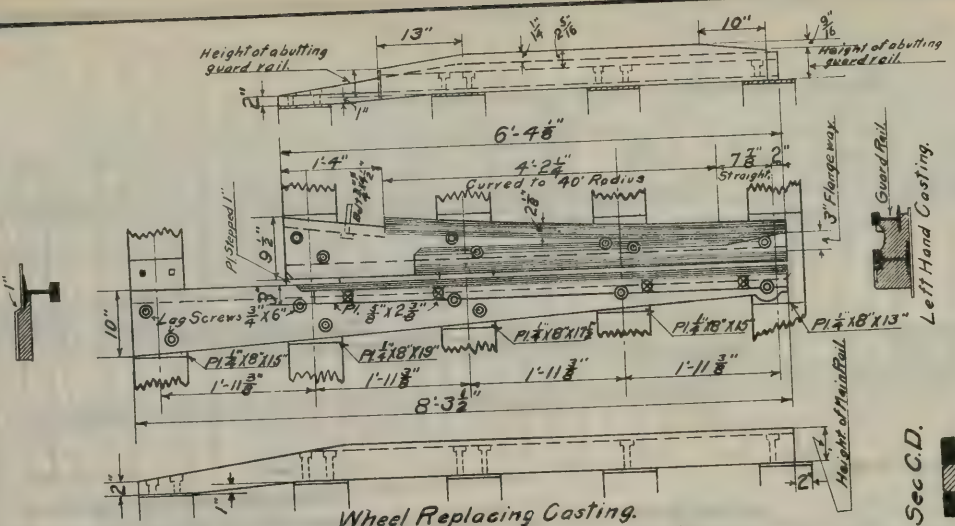
— MICHIGAN CENTRAL R.R. —

GUARD RAILS.

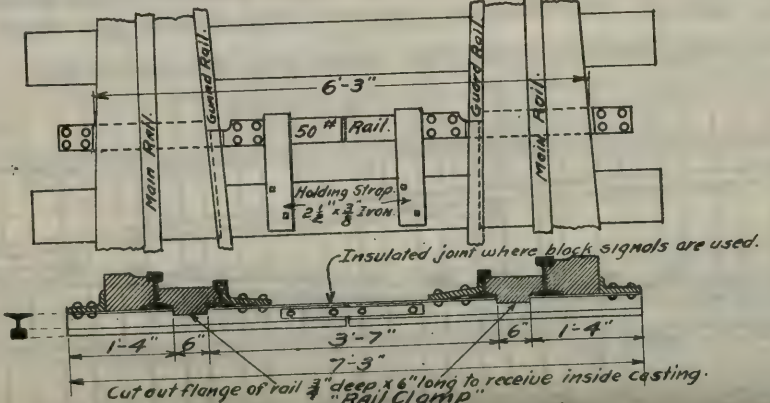
Office of the Bridge Eng.
Detroit Mich.
August 1911. A-10.

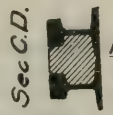

3"x4"x9" Wood Block.
7"x12" Tie Plate every 2nd tie.
Gauge Line.
1" Bolts.
3-4x9 Wood Blocks.
10'-0"
4'-8½"
6'-6"
Section.
Ties 7"x9"x10'-0
C.I. Block
Plan.
Note:- Guard rails are brought together about 75'-0" from end of bridge.
Sec. A-B.
Ties 7"x9"
4'-6"
Main Rail.
Gauge Line.
90# Rail
Guard Rail
2'-0"
7'-0"
5'-0"
1'-0"
Sect. C.D.
Plan.
Elevation.
P. & L.E.R.R.
Road #55
A-11

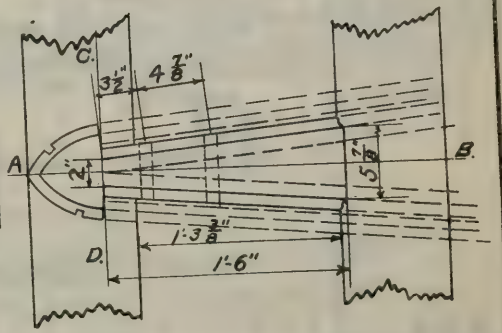

Approach.
Bridge.
Point Casting.
8" Flangeway.
This distance to be made as near 50 ft. as placing of point casting will permit.
Note.
Rail brace every 3rd tie on bridge; every 2nd tie on straight portion of guard rail on approach, & every tie on curved portion of guard rail on approach.
-Guard Rail.-
C.I. Separators every 4th tie on approach & 6th on bridge.
Approach
Bridge.
Straight Guard Rail 15' lg.
Curve to 40' R.
Point Casting.
3" Flangeway.
From 30' to 50'
Guard Rail with wheel replacing casting.
Southern Pacific & Union Pacific Rys.
Road # 59
A-12.

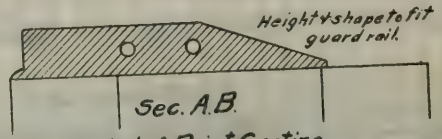


Wheel Replacing Casting.



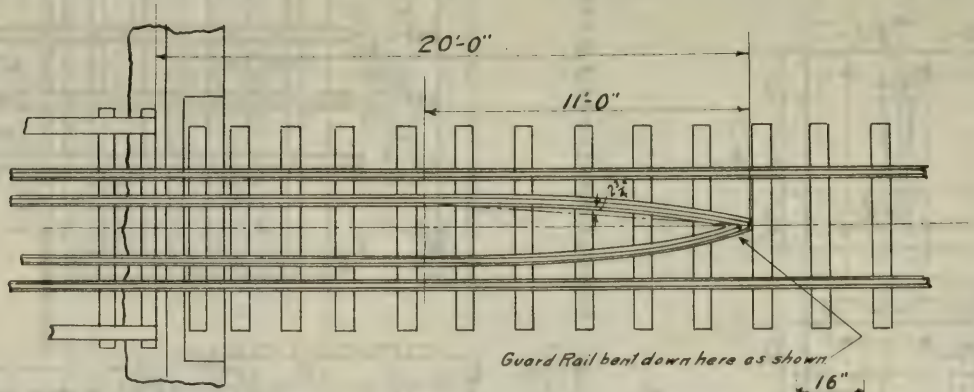


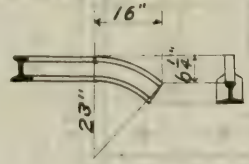


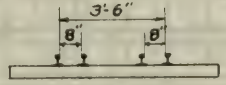


Detail of Point Casting.

Southern Pacific & Union Pacific.
Road # 59
A-12-A.

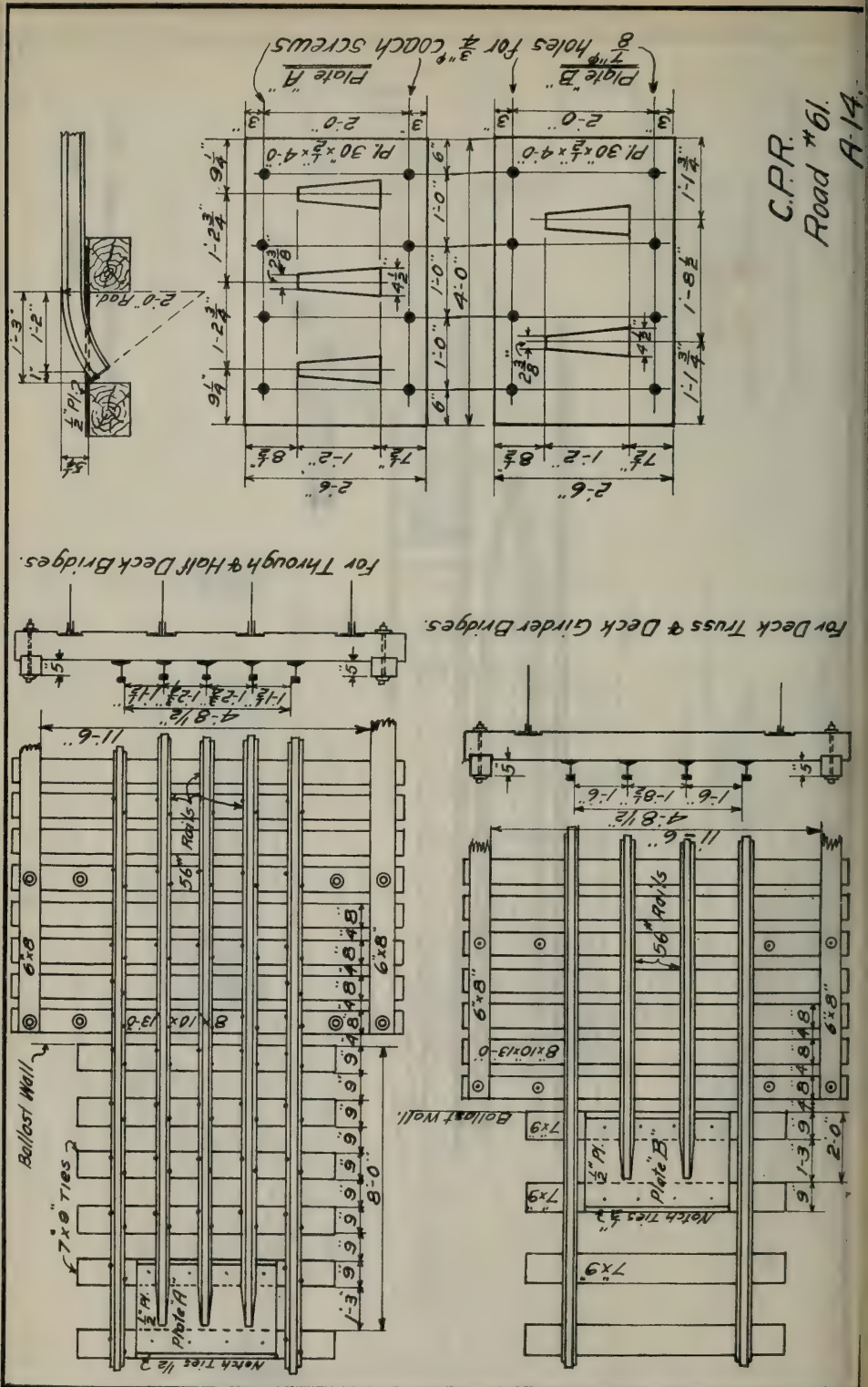






PHILIPPINE ISLANDS RY.
ROAD #60.

A-13.


C.P.R.
Road #61.
A-14.
Plate "A"
Plate "B"
8 holes for ¾" Coach Screws
Pl. 30"×½"×4'-0"
2'-6"
2'-0"
4'-0"
1'-0"
1'-2¾"
1'-8½"
1'-1¾"
2'-0" Rad.
For Through & Half Deck Bridges.
For Deck Truss & Deck Girder Bridges.
4'-8½"
11'-6"
56# Rails
6x8"
8x10x13'-0"
7x9"
Notch Ties ½"
Plate "B"
Ballast Wall
7"x8" Ties
8'-0"
1'-3"
2'-0"

Appendix B.

El Paso & Southwestern:

14. On our high bridge over the Rio Grande River, we have installed the Latimer rerailing frog, the frogs being located at the point where the guard rails begin to curve into the terminal point in center line of track.

Nashville, Chattanooga & St. Louis:

21. The rerailers are used also without guard rails.

Illinois Central:

44. All through bridges and high steel viaducts are being equipped with rerailing devices, especially where a high rate of speed is maintained. Some few high and long wooden structures have been equipped with rerailing devices.

These rerailing devices are placed 12 ft. 6 in. from the end of the structure on the roadbed. The inside guard rail is continued out 20 ft. past the rerailing device running to a point connected by a cast steel casting 2 ft. 3 in. long and bolted to casting with 2¾-in. bolts. The outside guard timber is connected near the rerailing casting with a steel guard rail 18 ft. 7 in. long, and turned out at the end near the guard rail point 1 ft. 7 in. from the running rail. Rerailing device consists of two separate castings made of semi-cast steel. Casting between the traffic rail and the outside special guard rail is 5⅝ in. high and shaped in between both rails. Casting has a 10-in., flat-bearing surface. Casting, between traffic rail and inside guard rail, is 5 ft. 8 in. long and 9 31/32 in. wide. Casting has a rib 3½ in. high at center running down to a flat surface at each end. This rib is 2½ in. at center of casting from ball of main rail, beveling back at ends of casting 5½ in. to guard rail. See print attached.

Pittsburg & Lake Erie:

55. Rerailing devices are used on a number of our Company's bridges. See Appendix A11.

Appendix C.

Nashville, Chattanooga & St. Louis:

21. The front truck of trailer on a double load of piling rerailed at Running Water bridge, No. 136, Chattanooga Division, in 1908. Speed of train such that although derailment was noticed while approaching bridge, engine driver could not stop the train before the derailed car was derailed. This is the only test as yet. All bridges are not yet equipped.

Illinois Central:

44. Rerailing devices have proved effective. An engine weighing 100 tons was rerailed on a high viaduct while running at 30 miles an hour. Freight cars have been rerailed on another high viaduct and on a long through truss bridge.

Pittsburg &Lake Erie:

55. A rerailing device at the south end of the bridge over the Youghioghany River at McKeesport has rerailed cars frequently, as evidenced by cut ties approaching the rerailing device and vanishing at that point.

Other cars have been rerailed at the device placed at the end of the bridge over the Mahoning River at Lowellville Junction.

At both of the above points the absence of the rerailing device would undoubtedly have resulted in the destruction of the bridge.

Appendix D.

Wheeling & Lake Erie:

7. Our "T" rail guard rails extend varying lengths beyond the ends of the bridges, dependent upon the alignment of the track and the length and character of the bridge. If there is a sharp curve in close proximity and it is a through bridge of considerable length, our "T" rail guard rails extend 200 ft. beyond the end of the bridge on the side where these conditions exist. Generally our guard rails extend out 90 ft. beyond the end of the bridge.

Philadelphia & Reading:

16. When a No. 6 frog is used, the guard rails on approach end are extended 41 ft. 3 in. On the trailing end the guard rails are extended 20 ft. and the rails bent until the ends are 18 in. apart. When No. 8 frog is used, the guard rails are extended 54 ft. 7 in. on the approach end. On the trailing end they are extended 35 ft and bent as above. When a No. 10 frog is used the guard rails on the approach end are extended 68 ft. On the trailing end the guard rails are extended 50 ft. and bent as above. On single track the frog points shall be used on both ends. On double track the frog is used only on the ends facing traffic.

Gulf, Colorado & Santa Fe:

34. We extend the guard rails on single track 44 ft. 6 in. beyond the last bridge tie and is brought to a point at both ends beyond the bridge. On double track we extend the guard rails similar to above at the end of the bridge toward approaching trains and extend the rails 10 ft. beyond the other end of the bridge. The rail at this end of the bridge continues tangent and 8 in. of the extreme end of the trail, and is then bent down to an angle of 45 degrees.

Great Northern:

35. Guard rails are generally extended 90 ft. beyond the bridge. In Canada the guard rails of deck bridges and timber trestles are extended from 24 ft. to 32 ft. beyond the bridge. For through bridges the rails extend from 75 ft. to 90 ft. beyond the bridge.

Lehigh Valley:

43. On double track, guard rails extend 200 ft. from bridge on approach side and 30 ft. from bridge on leaving side, where speed is over 35 miles an hour. When speed is less than 35 miles an hour, the guard rails extend only 100 ft. on approach side. On single track the guard rails extend 100 ft. or 200 ft. from end of bridge, dependent on whether speed is low or high.

Chicago, Rock Island & Pacific:

51. The minimum length for the extension of guard rails beyond the bridge is 60 ft. This length is dependent upon local conditions. In cases where the span has a pile or timber trestle approach, the guard rails should extend over this approach and 60 ft. beyond, providing the approach is not more than 300 ft. long. In case the approach is more than 300 ft. long, the guard rail should extend 300 ft. from the end of the bridge.

Appendix E.

New York, Chicago & St. Louis:

9. One instance is given where a derailed car ran across a through bridge about 60 ft. long, in which the wheels were apparently restrained by the guard rails.

Cleveland, Cincinnati, Chicago & St. Louis:

10. A derailed car on a high viaduct was safely carried a distance of 400 ft. around a 6-degree curve, guided by both guard rail and guard timber. The wheels bore against both the guard rail and guard timber, and it is hard to say which did the greater share of the work.

Lake Erie & Western:

11. Within the last two years we have had five derailments which we consider would have been considerably more serious if it had not been for the guard rails. In one case the derailed truck struck the point of the guard rails within a few inches of the center of the track and the truck was pulled over so that the car safely crossed the bridge and the wheels between the running rail and the guard rail.

Canadian Northern Quebec:

20. On our St. Maurice River bridge (mileage 80 from Quebec) we had metal guard rails between the rails and a freight train heavily loaded and a 125-ton engine ran off and traveled the total length of the bridge, which is 700 ft. long, and broke all the ties on the bridge. The height of the bridge is 100 ft. If we had not the guard rails on the inside of the rails, I am convinced the train would have gone into the river below.

Grand Trunk:

24. We have not experienced any trouble with cars going over the side of the bridge where guard rails were used, but have had cars go down the embankment after passing over a bridge, equipped with metal guard rails.

Santa Fe, Prescott & Phoenix:

25. One instance is given where a truck left the track and was badly skewed, approaching a bridge on a 12-degree curve. The guard rails caused the truck to swing in line and crossed the bridge without damage except marking the ties.

Norfolk Southern:

27. We have had only one derailment at bridges equipped with inner guard rail. It proved effective in this case and prevented what might have been a serious accident.

Lehigh Valley:

42. We had a number of cases where the guard rails guided the derailed train over the bridge. In one particular case, near one of our deck bridges, our milk train was derailed, five cars being off the track and if it had not been for the iron guard rails, some of the derailed cars would have been dashed into the ravine below.

Pennsylvania Lines West:

43. We know of cases where derailed wheels have crossed safely over a bridge on which there were guard rails, when the train would undoubtedly have been wrecked, had no guard rails been provided. As a specific instance, I abstract from report of a derailment on the Ohio Connecting Bridge (Pittsburg), on March 2, 1907:

"This bridge has a total length of 4520.2 ft., and crosses both channels of the Ohio River, Brunot's Island, and about 1400 ft. of the city, north of the river, at an elevation of 50 ft. in the clear above high water level.

"On the above date, a westbound freight train approached the bridge at a speed of about 19 miles an hour. The train comprised 32 cars, and the third car from the rear was a 70,000 lbs. capacity coal car, loaded. About 30 ft. from the east end of the bridge, a flange, on the front wheel of the rear truck of the above car broke, on an 11-degree approach curve, and the car was derailed at a point about 197 ft. on the bridge. From this point the derailed truck ran over the bridge about 740 ft., until train was stopped by wrecked floor and separated air hose.

"The running rails on the bridge were 85 lbs. per yard, and in addition to the standard outside timber guards, there were inner guard rails of old 85 and 80 lb. rail, placed 8 in. in the clear, inside of running rails, and spiked to every other tie."

The conclusion of the report stated:

"That the presence of the inner guard rails, beginning at the east end of span No. 3 (through span, 416.1 ft. long), undoubtedly prevented a serious accident to this span, which might possibly have been its destruction. That the continuance of the inner guard rails across span No. 3 and the deck spans, controlled the movement of the wrecked truck, and had it not been for the old ties on the deck spans, might possibly have prevented further accident.

"On span No. 3 the north wheels sheared the spikes on the north of inner steel guard rail, and the lateral force of wheels against this guard rail bent over the spikes on the south, moving rail inward an inch or two. When train reached the deck spans, the ties on which were nine years old, the inner steel guard rail was moved inward as much as a foot in places.

"That inner guard rails of steel rails are not desirable for bridges of this length or character, because spikes are sheared by derailed wheels, and guard rails moved inward, even on perfect ties.

"That inner guard rails be used, consisting of timber, 7x8, laid flat and lock-dapped to the ties." (See blue print of Drawing No. 13977, Special Floor Deck Construction for Bridges. This plan was made to carry out the above recommendation.)

Illinois Central:

44. Guard rails have proved efficient in practically all cases, but no specific instance is given.

Chicago, Milwaukee & St. Paul:

45. We have had a number of cases of derailments on bridges which have clearly and unequivocally demonstrated the value of the guard rails and especially of the type we use. Several of these cases have been on important bridges, where the result of a car breaking through or running off the floor would have been a very serious matter. One case that I remember was of a heavily loaded refrigerator car, which passed over three 200-ft. spans on a 6-degree curve. Another case was on one of our Mississippi River bridges, where the derailed wheels traveled over several spans, and a considerable distance of the approach, part of which was on a curve. In both of these cases there was no injury to the structure, and no complete wreck of the car and we are firmly convinced that the type of guard rail used, which was the same as shown in attached sketch, was responsible for our escaping with so little damage.

I might add that this type of guard rail has been the standard with this company for considerably more than twenty years past.

Boston & Albany:

47. We have had numerous instances where a derailed engine went over the bridge safely on the 4 in. x 10 in. and was wrecked beyond the bridge. We have had several cases during the past year where there

does not seem to be any question but that the bridge would have been wrecked if guard rails had not been provided.

Central of Georgia:

52. I have personal knowledge of several instances where derailed wheels have been guided safely over bridges when they would otherwise have been dumped into the stream.

Central Railroad of New Jersey:

56. We had a case where an engine tank got off the track and ran for a distance of a quarter of a mile before it reached the guard on the bridge. About that time the truck began to get crosswise of the track. It struck the guard rail just behind the frog point and straightened up and ran for a distance of 1500 ft., keeping parallel to the rails until the engine stopped.

Appendix F.

Great Northern:

35. We use guard rails on all steel bridges with through spans and in some special cases, as with bridges on curves, with deck spans. For Canadian lines we are placing guard rails on all bridges 50 ft. long and over. The Canadian standard consists of second hand tee rails bent together at each end and closed by means of a second-hand frog point.

Chicago & Northwestern:

46. We use guard rails on the following bridges:

(a) Steel bridges, open floors, on tangent 80 ft. long and longer.

(b) Steel bridges, open floor, on curves, 50 ft. long and longer.

(c) Wooden trestles which serve as approaches to steel bridges which are equipped with guard rails.

Chicago, Rock Island & Pacific:

51. Inner guard rails should be placed on all through truss and through girder bridges 70 ft. or more in length which are on curves or within 600 ft. of a curve. In case it is thought desirable to place an inner guard rail on a high steel deck bridge, a high trestle bridge, or a special case not herein provided for, the matter should be referred to the Chief Engineer.

Philadelphia & Reading:

16. Guard rails are full spiked their entire length. Where rails are bent inward to meet frog point, rail braces are used on the inside on every other tie.

Nashville, Chattanooga & St. Louis:

21. On the bent portion the rails are braced with rail braces on the inside on every tie.

Santa Fe, Prescott & Phoenix:

25. Guard rails to be spiked to every third tie. Point rails to be full spiked.

National Railways of Mexico:

26. Guard rails full spiked their entire length.

Norfolk Southern:

27. Braces are used every fourth tie on the inside of the entire length of rails.

Pittsburgh, Shawmut & Northern:

33. Guard rails spiked every other tie. Frog points are notched 2 in. into ties.

Great Northern:

35. When the bulb angle and timber guard rail is used the timber is bolted to the ties on bridge every 5 ft. On approach the timber is secured to track ties by boat spikes in every other tie.

When tee rails are used they are spiked to every other tie on the straight portion and to every tie on the curved portion of the rails, where bent to meet the frog point.

Appendix G.

INFORMATION AS TO THE MANNER OF SECURING GUARD RAILS TO BRIDGE FLOORS, ETC.

Toledo & Ohio Central:

2. Guard rails to be fully spliced, bolted and spiked.

Baltimore & Ohio:

3. Guard rails to be spiked every second tie on bridge. Full spike on approaches. Angle bars to be full bolted.

Wheeling & Lake Erie:

7. Guard rail splices to be 4-bolted. Guard rails to be full spiked the entire length.

Vandalia:

8. Guard rails to be full spiked their entire length. Where the guard rails run parallel to main rail, cast rail braces are used on the inside on every fourth tie. On the portion where the rails are converged to the frog or cast point the rail braces are used on the inside on every tie.

Cleveland, Cincinnati, Chicago & St. Louis:

10. Guard rails to be full bolted and spiked. Lag screws used in some cases on curves to fasten guard rails to ties.

Lake Erie & Western:

11. Guard rails to be spiked to every tie off the bridge and to each tie on the bridge to which the main rail is spiked. Splices to be full bolted.

Norfolk & Western:

12. Guard rails to be spiked to every second tie on bridge and full spiked on approaches.

Buffalo, Rochester & Pittsburgh:

13. Guard rails to be spiked to every other tie on bridge and to every tie off bridge. Splices to be full bolted with all nuts on the inside.

Hocking Valley:

15. Guard rails to be full spiked to ties. Rail braces to be used on the inside on every fourth tie where rails are parallel to main rail. On the bent portion the rail braces are used on every tie.

New York, New Haven & Hartford:

39. Guard rails spiked every other tie.

Pennsylvania Lines West:

43. When tee rails are used they are full spiked and bolted, with all nuts on the inside. Rail braces on the inside are used on every fourth tie on straight rails and on every tie where rail is curved to meet the cast or frog points. On trailing ends the braces are not used on the bent rails, but are full spiked.

On important bridges where the angle and timber rails are used, the timber is bolted through every fourth tie on bridge.

Chicago & Northwestern:

46. On bridge floors the 4 in. x 10 in. guard rail timber is fastened to every tie by a ½-in. boat spike. The angles are fastened to the side of the 4 in. x 10 in. with ½-in. wood screws. No information is given as to the bolting or spiking of tee rails used on the approaches to bridges.

Michigan Central:

50. Guard rails are spiked every other tie on bridge and full spiked on approaches.

Chicago, Rock Island & Pacific:

51. Guard rails full spiked their entire length.

Central of Georgia:

52. Guard rails are full spiked off the bridge and spiked to every other tie on the bridge.

Grand Rapids & Indiana:

53. Rail braces are used every fourth tie.

Pittsburg & Lake Erie:

55. Inside of re-railing devices is braced by cast braces.

Central Railroad of New Jersey:

56. Where rails are curved to meet the cast point, they are braced on the inside by cast braces on every other tie.

Appendix H.

DESCRIPTIONS AND PHOTOGRAPHS SHOWING RESULTS OF TESTS MADE BY THE MICHIGAN CENTRAL RAILROAD IN 1892 ON THE VALUE OF GUARD RAILS ON BRIDGES.

The tests described below led to the adoption of the "Jordan Guard Rail" as a standard for the Michigan Central Railroad.

It differs materially from other styles of guard rails in having three inside rails instead of two as commonly used and also in the arrangement of the ends of the guard rails which in this style, are kept an equal distance apart from one end to the other; the ends being rounded off so as to run underneath the plate fastened to the ties.

The photographs taken at the time of the test have been numbered from 1 to 8 and a description of the same as given by an eye witness is printed below, to make the understanding of the photographs clearer.

Fig. 1. Shows the tracks made by a car having the front wheels of the front trucks derailed. It will be noticed that the tendency is for these wheels to slue around so that they finally derail the rear wheels of the truck. By the time that the mark shows that the rear wheel is off the front wheel is on the wrong side of what would be the end of the curved point on the Latimer Guard. On the Jordan 3-rail guard, the left hand front wheel would be between the first and second guard rail, the left hand rear wheel between the third guard rail and the left hand running rail and as there is nothing to deflect them, these rails would, very likely, guide it across the bridge in the same position that it entered it.

Fig. 2. The Jordan Guard Rail. Forward truck derailed and slued, rear pair of wheels between running rails and guard rails on each side. Forward pair of wheels lifted up so as to clear everything.

Fig. 3. Jordan Guard Rail. The rear truck is derailed. The forward wheels are, in this case, not lifted, as all the other three wheels of the truck bear evenly on the running rails and on the center guard rail.

Fig. 4. Jordan Guard Rail. Both front and rear trucks derailed; front truck, front car wheels outside of the running rail, front near wheel riding first guard rail. The rear truck, the condition of this is just opposite the condition of the front truck.

Fig. 5. Jordan Guard Rail. Both trucks derailed; front truck, front near wheel between near running rail and first guard rail. Rear near wheel outside near running rail just above top of ties. Rear forward wheel between second and third guard rail. Rear truck, front near wheel outside of near running rail; front far wheel on top of far running rail; rear near wheel outside of near running rail down on ties breaking ends of same; rear far wheel between third guard rail and far running rail.

Fig. 6. Jordan Guard Rail. Front truck derailed, both near wheels outside of near running rail; front far wheel between second and third guard rail; rear far wheel between third guard rail and far running rail. With only two guard rails, the forward wheels would be apt to slue around and drag the rear far wheel off the guard rail and send the car clear outside of the bridge. While with the three guard rails, the center rail holding forward far wheel, counteracts the tendency to slue farther around.

Fig. 7. Jordan Guard Rail. Both trucks derailed. Front truck and rear near wheels outside and below ends of ties; front and rear far wheels against center guard rail and held there. Rear truck badly slued; both front wheels, outside near running rails; the rear wheels skidding on

FIG. 1.

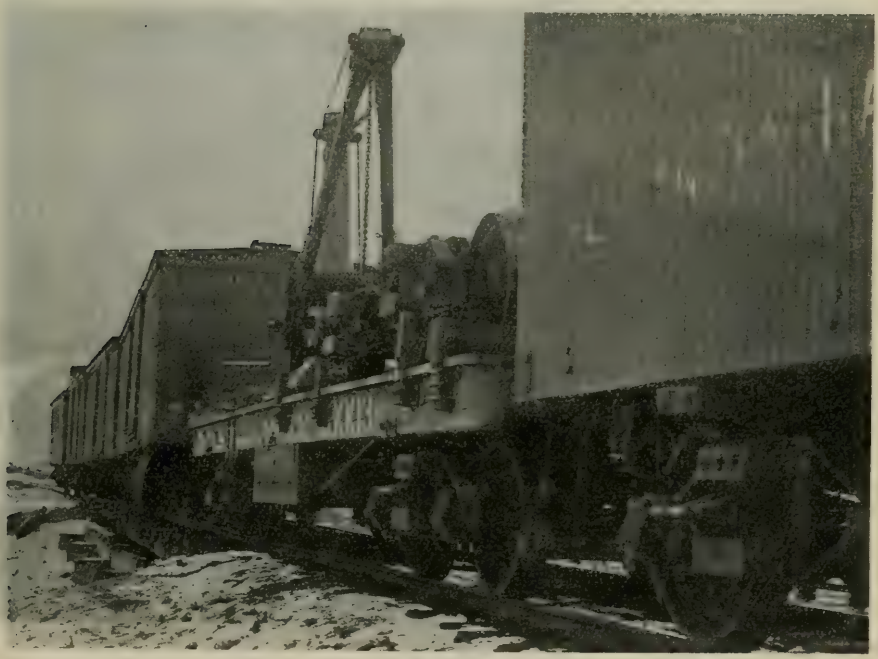


FIG. 2.

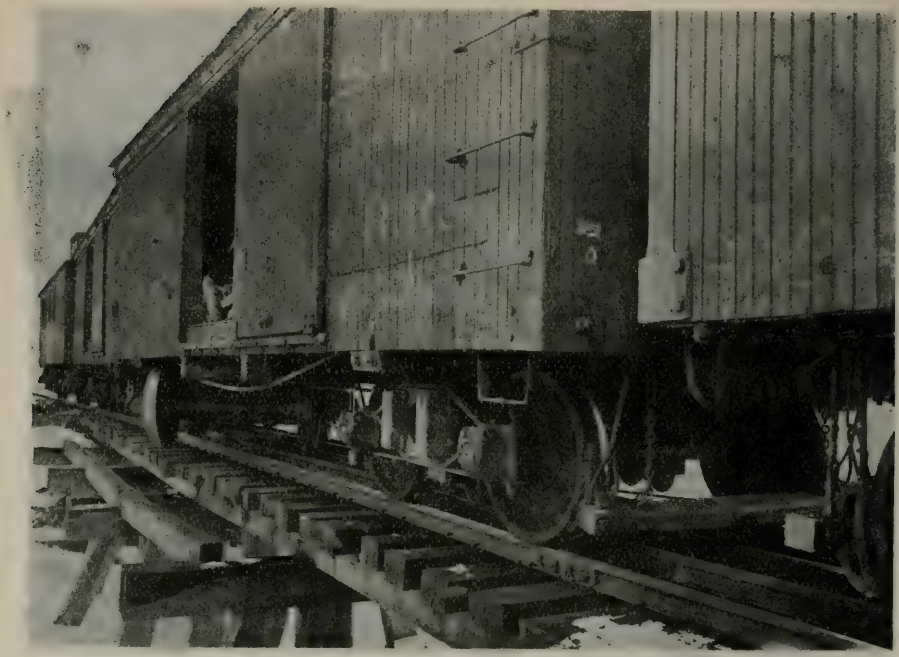


FIG. 3.

FIG. 4.

FIG. 5.

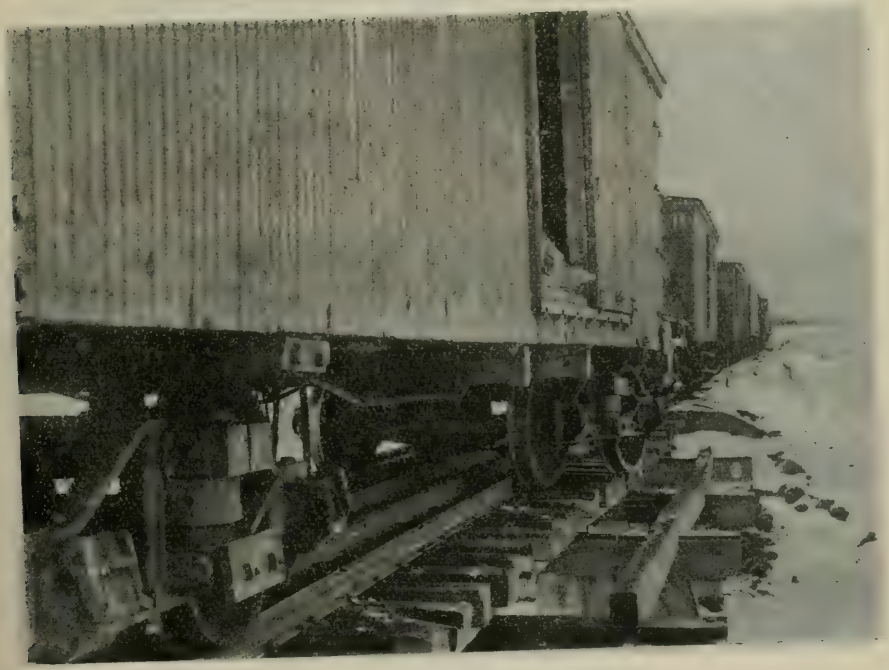


FIG. 6.

FIG. 7.

FIG. 8.

near running rail and first guard rail and between second and third guard rail. This car passed over the bridge.

Fig. 8. Shows a bridge with Jordan Guard Rail after badly derailed cars have been dragged across same. It will be noticed that the damage is very slight; the ties are only bruised on the top, none of the ties are broken. On this particular bridge the guard rails were of course spiked down a good deal firmer than is usually the case, having four spikes to each tie. But even with our usual way of spiking every second tie, there is no record of our bridge floors having to be repaired after a wreck when we had our standard guard rail on the bridge.

The center guard rail certainly helps to preserve and hold the floor intact in case of a derailment. On our Grand River Bridge in Canada, a deck truss bridge of four spans 150 ft. long, we have had three wrecks. At the time of the first derailment this was a single track, open floor deck truss bridge, with ties resting on the top chord. The bridge had been equipped with our standard guard rail shortly before the derailment, and this very likely saved the bridge; the cars piled up on the bridge, but left the floor intact and only delayed traffic long enough to clear away the wreck.

At the second derailment the bridge had been rebuilt as a ballast floor deck truss, but the guard rails had not been put on more than one track at that time. The cars piled up on the bridge, covering both tracks and tore the track which had no guard rails on, all up, while the other track was all right for traffic as soon as the wreck had been cleared off.

The third derailment at this bridge happened a little over three years ago and in this case the car was derailed before it reached the bridge and passed clear across the bridge, skidding on the guard rails, piling up and causing a wreck as soon as it had passed over the bridge and run off the guard rails.

We had a derailment in 1907 on a 150 ft. deck plate girder draw bridge, with open floor, in which also a car was derailed before entering the bridge and the wheels were between the outer and the center guard rail, with the truck slued, in which position they skidded over the bridge. The car left the track and went into the ditch a short way beyond the ends of the guard rails. The floor of the bridge was not damaged at all.

Appendix I.

FIRE PROTECTION ON WOODEN BRIDGES AND TRESTLES.

Number	Railroad	Question No. 1 Do you use any method of protection against fires on your timber bridges or decks of steel bridges?	Question No. 2 What method do you use?	
			Timber Bridges	Steel Bridges
1	S. P. & Seattle	Yes	Gravel	None
2	A. T. & S. F.	Yes	Gravel	None
3	Pitts., Shawmut & North'n.	Yes	Cinder or Clay	None
4	Norfolk & Western	Yes. Appendix 4	Gravel	None
5	El Paso & So. Western	Yes. Appendix 5	Rock	None
6	Illinois Central	Yes. Appendix 6	2" Ballast	2" Ballast
7	C. R. I. & P.	Yes. Appendix 7	Gravel	None
8	C. M. & St. P.	Yes. Appendix 8	3" Gravel, Gal. Iron	None
9	Virginian	Yes	Gal. Iron on High Trestles.	None
10	Maine Central	Yes. To a limited extent.	Clapp's Fire resist Paint	None
11	Michigan Central	Yes. Appendix 11	Gravel or Rock, Gal. Iron	None
12	Great Northern	Yes	Gal.Iron,Gravel or Rock	Gal. Iron proposed
13	Phila. & Reading	Yes. Appendix 13	Sheet Iron	None
14	N. C. & St. L.	Yes. Appendix 14	Gal. Iron	None
15	Penna. Lines	Yes. Appendix 15	See Appendix	
16	L. & N.	Yes. Appendix 16	Gal. Iron	None
17	Mo. Pac.	Yes	Gravel, Gal. Iron	None
18	M. & St. L. and Ia. Cent.	Yes	Gal. Iron	None
19	G. C. & Santa Fe	Yes. Appendix 19	Gal. Iron	None

Norfolk & Western:

4. On one timber trestle, 200 ft. long, we put a gravel floor as trial three years ago. As this bridge is on a curve, we have had to keep the gravel from shaking down to the low rail. This is done by the trackmen. It is a defect in the plan, and longitudinal obstructions should be placed to prevent the gravel from shaking down.

Before fireproofing this trestle we had eight to ten small fires a month and one complete destruction, but have had no fires since it has been fireproofed.

El Paso & Southwestern:

5. On our now obsolete design of originally open-floor timber bridges we fireproof the floor by filler planks placed between the ties in which the deck is covered with broken rock to a depth of 2 inches above the rail. This protection has proven quite effective. We have record of only one bridge so fireproofed having caught fire in the deck.

Illinois Central:

6. Several years ago when we started the use of creosoted material we put in creosoted ties, and in order to protect ties we used what was called a protected deck. This consisted of placing some 2x6 material

between the ties and covering the deck with about 2 inches of ballast. Have had no fires on bridges fireproofed.

Chicago, Rock Island & Pacific:

7. In 1909 we started the use of ballasted deck trestles. For the year ending June 30, 1910, we had 368,253 lin. ft. of pile trestles, including approximately 7,500 ft. of ballast deck trestles. During this year we had 88 fires.

Question No. 3 Have you ever suffered from a fire loss on bridges fireproofed by your method? If so, state where fire originated.	Question No. 4 Give number of lin. ft. fireproofed.		Question No. 5 Give approximate figures showing decrease in fire losses since you commenced using your method.
	Timber Bridges	Steel Bridges	
Yes. Burning rubbish beneath...	20000	.....	Work done under construction.
Yes. Fire caught in piling.....	6000	.....	Decrease very noticeable.
No.....	1000	.....	
No.....	200	.....	
Yes. One caught in deck.....	.....	.....	
No.....	2000	1600	
No.....	.....	.....	
.....	.....	.....	
Yes.....	47417	.....	Fire reported in 1911, 50% less than corresponding period 1910
No.....	1330	.....	
No.....	1160	.....	
.....	Entire System	None to date.	
.....	.....	.....	
Yes. Occasionally.....	94548	.....	
.....	.....	.....	
.....	.....	.....	
.....	10000	.....	
.....	.....	.....	
None in deck. Few in piling.....	.....	.....	

The statistics for 1911 have not yet been completed but we now have approximately 10,000 lin. ft. of ballast deck trestles. For the nine months ending March 31, 1911, the fire loss amounted to $6,444.71. We also have a large number of trestles having "fireproof deck," which consists of 1-inch-thick boards between ties and covered with crushed stone, gravel or slag. We have no means of telling just how much the use of fireproof or ballast deck trestles has decreased our fire losses, except that in not a single case, since we have adopted their use, has a fire been reported on any of them.

Chicago, Milwaukee & St. Paul:

8. This company uses two methods of protecting the floors of timber bridges from fires originating from locomotives. No method has been adopted for protecting timber floors on steel bridges.

One of the methods of fire protection used by this company consists of a layer of gravel spread over the ties to a depth of about three inches. The gravel is supported between the ties by nailing one-inch

boards either over the openings or between the ties. The guard timbers are protected by strips of galvanized sheet iron.

The other method used by this company consists of laying strips of galvanized iron so as to completely cover the ties and guard timbers.

Although no means have been adopted by this company for protecting the timber floor of steel bridges, however, the danger arising from fires on timber floors on deck girders has been eliminated on all of the more recent deck girder bridges by the use of either reinforced concrete slab ballast floors or creosoted timber ballast floors.

This company has two instances on record of bridge fires starting on bridges with fire protection. The first instance was on the Pacific

Number	Railroad	Question No. 6 Give approximate cost per lin. ft.	Figure	Remarks
1	S. P. & Seattle	40c	.....	
2	A. T. & S. F.	50c	.....	
3	Pitts., Shawmut & North'n.	5c	.....	Method abandoned acc't rotting ties and str's.
4	Norfolk & Western	50c	9	
5	El Paso & So. Western	.....	.....	Method abandoned for solid floor.
6	Illinois Central	40c	.....	
7	C. R. I. & P.	30c	10	
8	C. M. & St. P.	Gravel, 50c Gal. Iron, 75c	11 12	Guard Timbers protected by gal. iron.
9	Virginian	.....	.....	
10	Maine Central	.....	.....	
11	Michigan Central	Gravel, 70c Gal. Iron, 75c	15 13, 14	
12	Great Northern	Gal. Iron—70c old plan, 97c new plan. Gravel, 32c	16, 17	
13	Phila. & Read.	.....	.....	
14	N. C. & St. L.	40c	.....	
15	Penn. Lines	.....	.....	
16	L. & N.	.....	.....	
17	Mo. Pac.	Gravel, 90c Gal. Iron, 50c	.....	
18	M. & St. L. and Ia. Cent.	50c	.....	
19	G. C. & St. Fe.	30c	.....	

Coast extension, where a bridge protected by gravel was destroyed. It is supposed that the high winds prevalent in this particular locality had blown the finer particles of ballast away and had shifted the coarser, thus leaving spots unprotected. The second instance occurred on a bridge which was protected by sheet iron only between the rails. In this case the fire started on the guard timbers.

At the close of the season of 1910 this company had protected 47,417 ft. of timber bridges against fire. At the close of the season of 1911 it is expected to have about 80,000 ft. of timber bridges so protected. In addition to this, all of the timber bridges on the C. M. & P. S. Ry. have been protected.

During the period between January 1, 1911, and August 25, 1911, there has been about 50 per cent. less fires reported, caused by locomotives, than for the corresponding time during 1910.

Wherever headroom is sufficient, we use a ballasted trestle. No fireproofing of open-deck trestles, but grass and rubbish is kept away from piles.

Michigan Central:

11. Up to about a year ago we did not attempt to protect any of our bridges against fire, but for the last year we have done so on timber bridges where we had to renew the bridge.

Philadelphia & Reading:

13. We use no protection on decks of steel bridges. On some wooden trestles we cover the floor with sheet iron.

We have some through wooden truss bridges where we use an inch layer of mortar on top of top chord, and cover the bottom of top chord with tin to prevent birds building nests between the eaves of chord.

Nashville, Chattanooga & St. Louis:

14. Chords, stringers and caps of wooden bridges are covered with galvanized iron primarily to prevent decay, but it also serves as a protection against fire. Ballast floors are used where possible in the renewals of wooden bridges, principally to diminish maintenance cost, but they are also considered as protection against fire. Protection against fire is not considered necessary on steel bridges.

On trestles protected with galvanized iron slight damage is frequent in ties, piles and bulkheads. Several short bridges have been completely destroyed by fire starting in bulkheads, it is supposed. No damage to ballast floor trestles is on record, but their use has only recently been begun. Most of our piling is of red cedar and quite old. Fires often originate in the rotten sap wood, but our effort is to keep this cleaned off.

Pennsylvania Lines:

15. On four of the nine operating divisions of this company fire protection is provided on some of their bridges. One division covers stringers between ties and tops of caps with galvanized iron, projecting one inch over each side of the stringers and caps. One division formerly covered tops of stringers between and under the ties with tin, but has discontinued the practice, as when the tin rusted through or broke and a spark passed through the opening to the dry timber beneath, the fire was difficult to reach, and in putting it out the fireproofing was entirely destroyed. This division has recently fireproofed the floor of one bridge over street by attaching on top of the plank floor old Winslow car roofing, scrapped at the shops during the repair of cars. This protection has so far been satisfactory.

A third division covers the stringers with galvanized iron. A fourth division covers the deck from guard rail to guard rail with galvanized iron, running the sheeting over the guard rail and 3 in. or 4 in. outside. These sheets do not run under the rail, but lap over the flanges. They have also fireproofed one bridge by covering the tops and sides of each

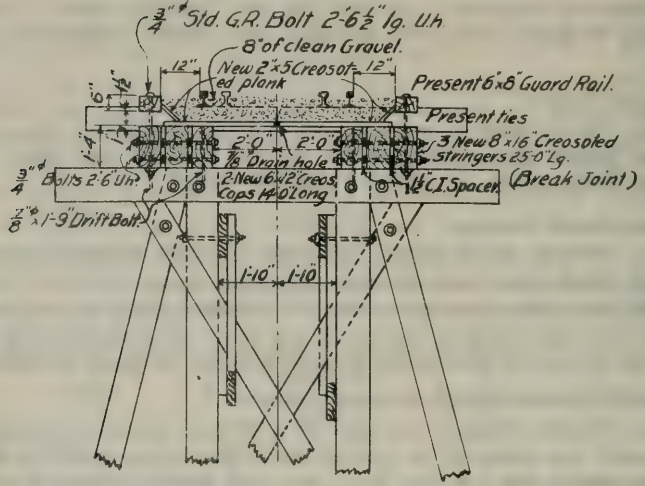


FIG. 9—NORFOLK & WESTERN RAILWAY.

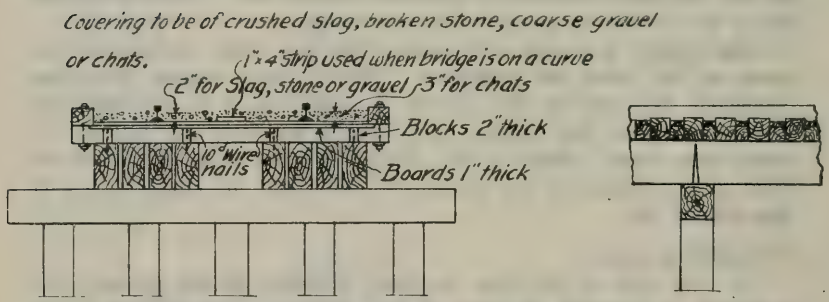

Covering to be of crushed slag, broken stone, coarse gravel or chats.
1"x4" Strip used when bridge is on a curve
2" for Slag, stone or gravel
3" for chats
Blocks 2" thick
10" Wire nails
Boards 1" thick

FIG. 10—CHICAGO, ROCK ISLAND & PACIFIC RAILWAY.

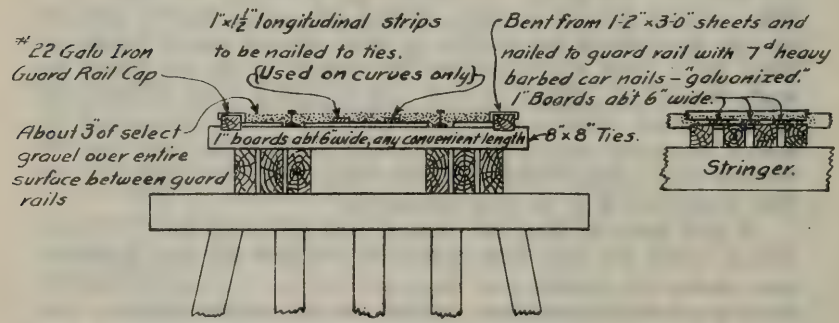
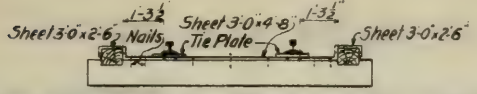
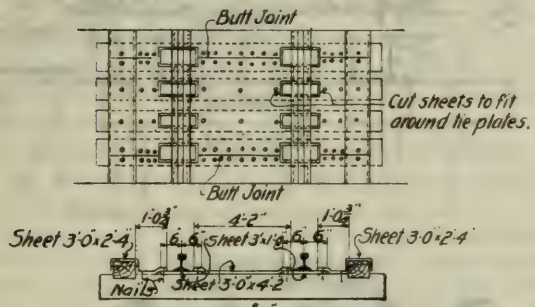

1"x1 1/2" longitudinal strips to be nailed to ties.
Used on curves only
Bent from 1'-2"x3'-0" sheets and nailed to guard rail with 7d heavy barbed car nails – "galvanized."
1" Boards abt 6" wide.
#22 Galv Iron Guard Rail Cap
About 3" of select gravel over entire surface between guard rails
1" boards abt 6" wide, any convenient length
8"x8" Ties.
Stringer.

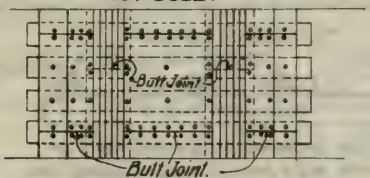
FIG. 11—CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.



STANDARD PLAN "B" FOR CURVES.



STANDARD PLAN "A" FOR TANGENT AND ELSEWHERE, WHEREVER TIE PLATES ARE NOT USED.



NOTE:-
SHEET METAL - #22 GALVANIZED SHEET STEEL
NAILS - 7d HEAVY BARBED CAR NAILS SPECIALLY GALVANIZED.

FIG. 12—CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.

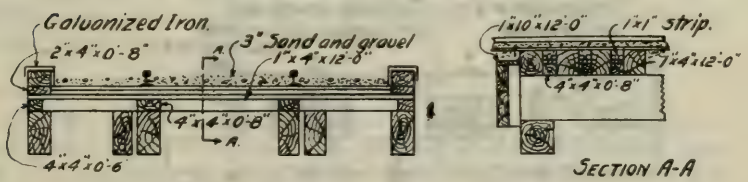


FIG. 13—MICHIGAN CENTRAL RAILROAD.

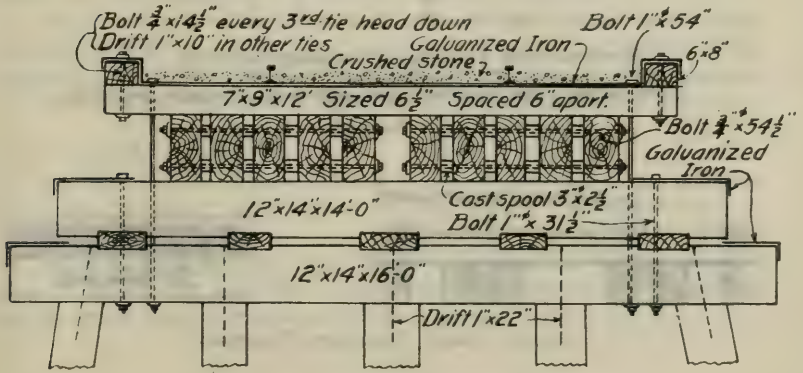


FIG. 14—MICHIGAN CENTRAL RAILROAD.

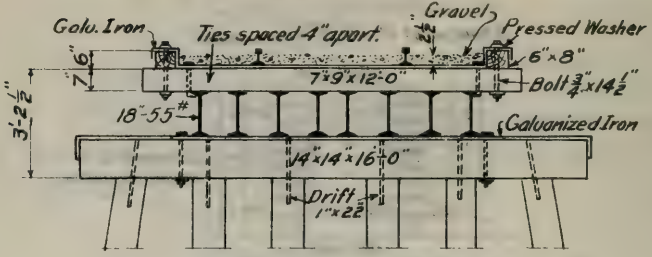
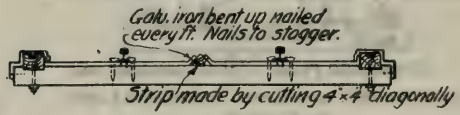
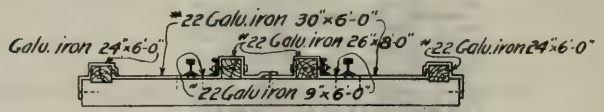


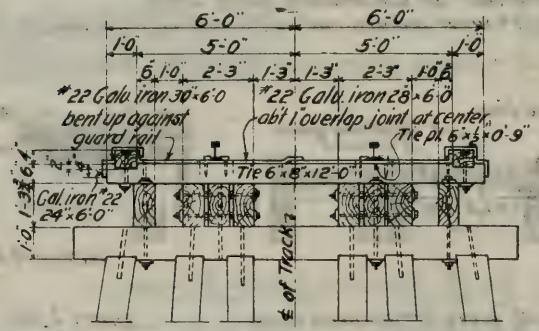
FIG. 15—MICHIGAN CENTRAL RAILROAD.



CROSS SECTION OF TIES WHERE ELECTRIC SIGNALS ARE USED.



SECTION SHOWING FIREPROOFING OF DECK WITH BULB ANGLE INNER GUARD RAIL.



SECTION FOR STANDARD FRAMED TRESTLE.

SAME DETAILS FOR FIREPROOFING USED ON ALL TIMBER BRIDGES.

FIG. 16—GREAT NORTHERN RAILWAY.

FIG. 17—GREAT NORTHERN RAILWAY.

tie between the guard rails and the guard rails themselves with galvanized iron sheeting.

Where only the stringers and caps are protected, the protection of the stringers only applies to wooden bridges. The caps of bents supporting steel bridges are protected. On divisions where the entire deck has been fireproofed, this fireproofing has been done on both timber and steel bridges.

We have not suffered any severe fire losses in the decks of bridges fireproofed, but one dangerous fire is reported and several small fires originating in the piling.

Reports from the four divisions on which some fireproofing has been applied show total length of bridge so protected about one mile, or a small proportion of the total number of bridges on these divisions.

The division on which the tops of caps and stringers are covered with galvanized iron, projecting 1 in. over the sides, report 75 per cent. decrease in the number of fires on bridges so protected. The other divisions report that, on account of the recent adoption of self-cleaning ash pans, which have largely increased the number of fires, statistics cannot be furnished.

The cost of protecting tops of stringers between ties and tops of caps with galvanized iron, projecting 1 in. over the sides of each, is reported 22 cents per linear foot of track. The cost of protecting the deck with old Winslow car roofing is reported at 10½ cents per linear foot of track, for labor only. The cost of protecting the entire deck with galvanized iron sheeting to lines 3 in. or 4 in. beyond the outside wooden guard rails varies from 79½ cents to $1.88 per linear foot, depending upon the location and size of bridge. This fireproofing was applied by a contract tinner and roofer.

Louisville & Nashville:

16. We do not fireproof the decks of steel bridges. We use creosoted timber wall plates under ends of steel bridges of moderate spans and we cover these creosoted timber wall plates with galvanized iron, partly as fire protection.

We cover tops of stringers and caps of open timber trestles with galvanized iron, partly for fire protection purposes and partly to increase the life of the timber. This method is effective for both purposes.

The above is the extent to which we go, fireproofing bridge structures.

Gulf, Colorado & Santa Fe:

19. We use No. 26 galvanized sheet iron on the tops of the stringers and caps. On open deck trestles we use crushed rock ballast on our creosoted bridges.

Do not recall any fire loss from bridges protected by galvanized iron or ballast, but have had some bridges damaged by fire originating in tall grass and communicated to the creosoted piling.

REPORT OF SPECIAL COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS.

W. G. Atwood, *Chairman;* J. C. Irwin, *Vice-Chairman;*
C. Frank Allen, C. A. Paquette,
E. F. Ackerman, H. C. Phillips,
Thos. Earle, J. H. Roach,
John P. Congdon, C. A. Wilson,
R. G. Kenly, H. A. Woods,
E. H. Lee, *Committee.*

To the Members of the American Railway Engineering Association:

Your Special Committee on Uniform General Contract Forms presents its report, as follows:

The Committee was instructed to complete its report and submit the General Construction Contract.

The meetings of the Committee were held as follows: At Chicago, Ill., August 2 and 3, 1912, attended by Wm. G. Atwood, Chairman; H. C. Phillips, Thos. Earle, C. A. Wilson and E. H. Lee; at Chicago, Ill., January 13, 1913, attended by Wm. G. Atwood, Chairman; H. C. Phillips, Thos. Earle, E. H. Lee and R. G. Kenly. Considerable work has also been done by correspondence, in which practically all members of the Committee joined.

In accordance with the suggestions made at the convention in 1912, the Secretary of the Association had a draft of the proposed form printed and sent a copy to the Senior officer of each railway having membership in the Association, with a request for a criticism of the contract by the Legal Department. There were seventy replies received, which may be classed as follows:

Number of Replies.	*Nature of Replies.*
One.	Thought it impractical to draw a Uniform Contract Form.
Six.	Preferred their own forms and made no other comments.
Thirty-five.	Approved of form, except in a few cases, where the lien clause was criticised.
Three.	Did not criticise, two of these being Canadian roads.
Twenty-five.	Made more or less extended criticisms.

The Secretary tabulated the replies, both the criticisms and the corresponding clauses of other contracts. This information was used by the Committee in revising the forms submitted for criticism. As this compilation would fill about one hundred and twenty-five printed pages, it

was considered undesirable to publish it. However, it is available at the office of the Secretary in case any of the members wish to consult it. Many of these criticisms concerned the detailed wording of the various clauses, and but few of them disapproved of any of the provisions as a whole.

The plan of having an agreement form of two pages to be used by itself for unimportant work and to act as a binder for the "General Conditions, Specifications and Plans," was approved by the convention of 1912. This agreement form as presented was also approved. As the result of legal criticisms received the Committee desires to recommend three amendments to this form, as follows:

In the third paragraph insert the words "except as hereinafter specified," making this paragraph read: "The Contractor shall furnish all necessary transportation, except as hereinafter specified, materials, superintendence, etc."

In the first line below the blanks left for the description of the work, insert after the word "attached," the words "identified by the signatures of the parties hereto" and eliminate the word "as," making this paragraph read: "in accordance with the plans hereto attached, identified by the signatures of the parties hereto, or herein described, and the following general conditions, etc."

Add to the next paragraph the words "time being of the essence of this contract," making this paragraph read: "The work covered by this contract shall be commenced..... and be completed on or before the.....day of....., 191...., time being of the essence of this contract....."

The Committee presents for approval:

(1) Amendments to form "A" as above.

(2) Form "B" as presented.

RECOMMENDATIONS.

(1) That Standing Committees which have prepared specifications be instructed to harmonize them with the approved contract form by the elimination of provisions which duplicate or nullify clauses of the contract form.

(2) That the Special Committee on Uniform General Contract Forms be discharged on account of the completion of the work assigned to it.

Respectfully submitted,

COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS.

AMERICAN RAILWAY ENGINEERING ASSOCIATION.

CONSTRUCTION CONTRACT.

A—AGREEMENT.

THIS AGREEMENT, made this.....day of.....in the year.....by and between.....party of the first part, hereinafter called the Contractor, and....., party of the second part, hereinafter called the Company.

WITNESSETH, That, in consideration of the covenants and agreements hereinafter mentioned, to be performed by the parties hereto, and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

The Contractor shall furnish all the necessary transportation, except as hereinafter specified, materials, superintendence, labor and equipment, and shall execute, construct and finish, in an expeditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer of the Company.....
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in accordance with the plans hereto attached, identified by the signatures of the parties hereto, or herein described, and the following general conditions, requirements and specifications, forming part of this contract.

The work covered by this contract shall be commenced.....
.....and be completed on or before the .....day of .....191...., time being of the essence of this contract.....
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And in consideration of the completion of the work described herein, and the fulfillment of all stipulations of this agreement to the satisfaction and acceptance of the Chief Engineer of the Company, the said Company shall pay, or cause to be paid, to said Contractor, the amount due the Contractor, based on the following prices:

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This agreement shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

In Witness Whereof, The parties hereto have executed this agreement in.....the day and year first above written.

Witness:

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CONSTRUCTION CONTRACT.

B—GENERAL CONDITIONS.

Bond.

1. The Contractor agrees, at the time of the execution and delivery of this contract and before the taking effect of the same, to furnish and deliver to the Company a good and sufficient bond of indemnity to the amount of.....dollars, as security for the faithful performance, by the Contractor, of all the covenants and agreements on the part of the Contractor contained in this contract. The security in such bond of indemnity must be satisfactory and acceptable to the Company.

This bond shall remain in force and effect in such amount, not greater than that specified, as shall be determined by the Chief Engineer, until the final completion and acceptance of the work.

Contractor's Understanding.

2. It is understood and agreed that the Contractor has, by careful examination, satisfied himself as to the nature and location of the work, the conformation of the ground, the character, quality and quantity of the materials to be encountered, the character of equipment and facilities needed preliminary to and during the prosecution of the work, the general and local conditions, and all other matters which can in any way affect the work under this contract. No verbal agreement or conversation with any officer, agent or employe of the Company, either before or after the execution of this contract, shall affect or modify any of the terms or obligations herein contained.

Intent of Plans and Specifications.

3. All work that may be called for in the specifications and not shown on the plans, or shown on the plans and not called for in the specifications, shall be executed and furnished by the Contractor as if described in both these ways; and should any work or material be required which is not denoted in the specifications or plans, either directly or indirectly, but which is nevertheless necessary for the proper carrying out of the intent thereof, the Contractor is to understand the same to be implied and required and shall perform all such work and furnish any such material as fully as if they were particularly delineated or described.

Permits.

4. Permits of a temporary nature necessary for the prosecution of the work shall be secured by the Contractor. Permits for permanent structures or permanent changes in existing facilities shall be secured by the Company.

Protection.

5. Whenever the local conditions, laws or ordinances require, the Contractor shall furnish and maintain, at his own cost and expense, necessary passageways, guard fences and lights and such other facilities and means of protection as may be required.

Rights of Various Interests.

6. Wherever work being done by Company forces or by other Contractors is contiguous to work covered by this contract, the respective rights of the various interests involved shall be established by the Engineer, to secure the completion of the various portions of the work in general harmony.

Consent to Transfer.

7. The Contractor shall not let or transfer this contract or any part thereof (except for the delivery of material) without consent of the Chief

Engineer, given in writing. Such consent does not release or relieve the Contractor from any of his obligations and liabilities under the contract.

Superintendence.

8. The Contractor shall constantly superintend all the work embraced in this contract, in person or by a duly authorized manager acceptable to the Company.

Timely Demand for Points and Instructions.

9. The Contractor shall not proceed until he has made timely demand upon the Engineer for, and has received from him, such points and instructions as may be necessary as the work progresses. The work shall be done in strict conformity with such points and instructions.

Report Errors and Discrepancies.

10. If the Contractor, in the course of the work, finds any discrepancy between the plans and the physical conditions of the locality, or any errors in plans or in the layout as given by said points and instructions, it shall be his duty to immediately inform the Engineer in writing and the Engineer shall promptly verify the same. Any work done after such discovery, until authorized, will be done at the Contractor's risk.

Preservation of Stakes.

11. The Contractor must carefully preserve bench marks, reference points and stakes, and in case of wilful or careless destruction, he will be charged with the resulting expense, and shall be responsible for any mistakes that may be caused by their unnecessary loss or disturbance.

Inspection.

12. All work and materials shall be at all times open to the inspection, acceptance or rejection of the Engineer or his duly authorized representative. The Contractor shall provide reasonable and necessary facilities for such inspection.

Defective Work or Material.

13. Any omission or failure on the part of the Engineer to disapprove or reject any work or material shall not be construed to be an acceptance of any defective work or material. The Contractor shall remove, at his own expense, any work or material condemned by the Engineer, and shall rebuild and replace the same without extra charge, and in default thereof the same may be done by the Company at the Contractor's expense, or, in case the Chief Engineer should not consider the defect of sufficient importance to require the Contractor to rebuild or replace any imperfect work or material, he shall have power, and is hereby authorized, to make an equitable deduction from the stipulated price.

Insurance.

14. The Contractor shall secure in the name of the Company and for its benefit policies of fire insurance on such structures and in such amounts as shall be specified by the Chief Engineer not exceeding.....

Indemnity.

15. The Contractor shall indemnify and save harmless the Company from and against all claims, demands, payments, suits, actions, recoveries and judgments of every nature and description brought or recovered against it, by reason of any act or omission of the said Contractor, his agents or employes, in the execution of the work by or in consequence of any negligence or carelessness in guarding the same.

Settlement for Wages.

16. Whenever, in the opinion of the Chief Engineer, it may be necessary for the progress of the work to secure to any of the employes of the Contractor any wages which may then be due them, the Company is hereby authorized to pay said employes the amount due them or any lesser amount, and the amount so paid them, as shown by their receipts, shall be deducted from any moneys that may be or become payable to said Contractor.

Liens.

17. If at any time there shall be evidence of any lien or claim for which the Company might become liable and which is chargeable to the Contractor, the Company shall have the right to retain out of any payment then due or thereafter to become due, an amount sufficient to completely indemnify the Company against such lien or claim, and if such lien or claim be valid, the Company may pay and discharge the same, and deduct the amount so paid from any moneys which may be or become due and payable to the Contractor.

Work Adjacent to Railroad.

18. Whenever the work embraced in this contract is near the tracks, structures or buildings of this Company or of other railroads, the Contractor shall use proper care and vigilance to avoid injury to persons or property. The work must be so conducted as not to interfere with the movement of trains or other operations of the railroad; or, if in any case such interference be necessary, the Contractor shall not proceed until he has first obtained specific authority and directions therefor from the proper designated officer of the Company and has the approval of the Engineer.

Risk.

19. The work in every respect shall be at the risk of the Contractor until finished and accepted, except damage or injury caused directly by Company's agents or employes.

Order and Discipline.

20. The Contractor shall at all times enforce strict discipline and good order among his employes, and any employe of the Contractor who shall appear to be incompetent, disorderly or intemperate, or in any other way disqualified for or unfaithful to the work entrusted to him, shall be discharged immediately on the request of the Engineer, and he shall not again be employed on the work without the Engineer's written consent.

Contractor Not to Hire Company's Employes.

21. The Contractor shall not employ or hire any of the Company's employes without the permission of the Engineer.

Intoxicating Liquors Prohibited.

22. The Contractor, in so far as his authority extends, shall not permit the sale, distribution or use of any intoxicating liquors upon or adjacent to the work, or allow any such to be brought upon, to or near the line of the railway of the Company.

Cleaning Up.

23. The Contractor shall, as directed by the Engineer, remove from the Company's property and from all public and private property, at his own expense, all temporary structures, rubbish and waste materials resulting from his operations.

Engineer and Chief Engineer Defined.

24. Wherever, in this contract, the word Engineer is used, it shall be understood as referring to the Chief Engineer of the Company, acting personally, or through an assistant, duly authorized, in writing, for such act by the Chief Engineer, and wherever the words Chief Engineer are used it shall be understood as referring to the Chief Engineer in person and not to any assistant engineer.

Power of Engineer.

25. The Engineer shall have power to reject or condemn all work or material which does not conform to this contract; to direct the application of forces to any portion of the work which, in his judgment, requires it; to order the force increased or diminished, and to decide questions which arise between the parties relative to the execution of the work.

Adjustment of Dispute.

26. All questions or controversies which may arise between the Contractor and the Company, under or in reference to this contract, shall be subject to the decision of the Chief Engineer, and his decision shall be final and conclusive upon both parties.

Order of Completion; Use of Completed Portions.

27. The Contractor shall complete any portion or portions of the work in such order of time as the Engineer may require. The Company shall have the right to take possession of and use any completed or partially completed portions of the work, notwithstanding the time for completing the entire work or such portions may not have expired; but such taking possession and use shall not be deemed an acceptance of the work as taken or used, or any part thereof. If such prior use increases the cost of or delays the work, the Contractor will be entitled to such extra compensation or extension of time, or both, as the Chief Engineer may determine.

Changes.

28. The Company shall have the right to make any changes that may be hereafter determined upon in the nature or dimensions of the work, either before or after its commencement, and such changes shall in no way affect or void this contract. If such changes make any change in the cost of the work, an equitable adjustment shall be made by the Chief Engineer to cover the same.

Extra Work.

29. No bill or claim for extra work or material shall be allowed or paid unless the doing of such extra work or the finishing of such extra material shall have been authorized in writing by the Engineer.

The price for such work shall be determined by the Chief Engineer, who may either fix a unit price or a lump-sum price, or may, if he so elects, provide that the price shall be determined by the actual cost, to which shall be added..... per cent. to cover general expense and superintendence, profits, contingencies, use of tools, Contractor's risk and liability. If the Contractor shall perform any work or furnish any material which is not provided for in this contract, or which was not authorized in writing by the Engineer, said Contractor shall receive no compensation for such work or material so furnished, and does hereby release and discharge the Company from any liability therefor.

If the Contractor shall proceed with such extra work or the furnishing of such extra material after receiving the written authority therefor, as hereinbefore provided, then such work or material, stated

in the written authority of the Engineer shall be covered, governed and controlled by all the terms and provisions of this contract, subject to such prices as may be agreed upon or fixed by the Chief Engineer.

If the Contractor shall decline or fail to perform such work or furnish such extra material as authorized by the Engineer in writing, as aforesaid, the Company may then arrange for the performance of the work in any manner it may see fit, the same as if this contract had not been executed, and the Contractor shall not interfere with such performance of the work.

Property and Right of Entry.

30. The Company shall provide the lands upon which the work under this contract is to be done, except that the Contractor shall provide land required for the erection of temporary construction facilities and storage of his material, together with right of access to the same.

The Contractor shall not ship any material or equipment until he has received written notice from the Engineer that he may proceed with said work or any part thereof.

Unavoidable Delays; Extension of Time on Parts of Work.

31. If the Contractor shall be delayed in the performance of the work from any cause for which the Company is responsible, he shall, upon written application to the Chief Engineer at the time of such delay, be granted such extension of time as the Chief Engineer shall deem equitable and just.

Suspension of Work.

32. The Company may at any time stop the work, or any part thereof, by giving ten (10) days' notice to the Contractor in writing. The work shall be resumed by the Contractor in ten (10) days after the date fixed in the written notice from the Company to the Contractor so to do. The Company shall not be held liable for any damages or anticipated profits on account of the work being stopped, or for any work done during the interval of suspension. It will, however, pay the Contractor for expense of men and teams necessarily retained during the interval of suspension, provided the Contractor can show that it was not reasonably practicable to move these men and teams to other points at which they could have been employed. The Company will further pay the Contractor for time necessarily lost during such suspension at the rate of.....per cent. per annum on the estimated value of all equipment and fixtures owned by the Contractor and employed on the work which are necessarily idle during such suspension, said rate of.....per cent. per annum being understood to include depreciation, interest and insurance. But if the work, or any part thereof, shall be stopped by the notice in writing aforesaid, and if the Company does not give notice in writing to the Contractor to resume work at a date within.....of the date fixed in the written notice to suspend, then the Contractor may abandon that portion of the work so suspended and he will be entitled to the estimates and payments for such work so abandoned, as provided in Section Thirty-eight (38) of this contract.

Expediting Work, Correcting Imperfections.

33. If the Chief Engineer of the Company shall at any time be of the opinion that the Contractor is neglecting to remedy any imperfections in the work or is not progressing with the work as fast as necessary to insure its completion within the time and as required by the contract or is otherwise violating any of the provisions of this contract, said Engineer, in behalf of the Company shall have the power, and it shall

be his duty to notify the Contractor to remedy such imperfections, proceed more rapidly with said work or otherwise comply with the provisions of this contract.

Annulment.

The Company, if not at fault, may give the Contractor ten (10) days' written notice, and at the end of that time if the Contractor continues to neglect the work, the Company may provide labor and materials and deduct the cost from any money due the Contractor under this agreement; and may terminate the employment of the Contractor under this agreement and take possession of the premises and of all materials, tools and appliances thereon, and employ such forces as may be necessary to finish the work. In such case the Contractor shall receive no further payment until the work shall be finished, when, if the unpaid balance that would be due under this contract exceeds the cost to the Company of finishing the work such excess shall be paid to the Contractor; but if such cost exceeds such unpaid balance, the Contractor shall pay the difference to the Company.

Company May Do Part of Work.

Upon failure of the Contractor to comply with any notice given in accordance with the provisions hereof, the Company shall have the alternative right, instead of assuming charge of the entire work, to place additional forces, tools, equipment and materials on parts of the work for the purpose of carrying on such parts of the work, and the cost incurred by the Company in carrying on such parts of the work shall be payable by the Contractor and such work shall be deemed to be carried on by the Company on account of the Contractor, and the Contractor shall be allowed therefor the contract price. The Company may retain the amount of the cost of such work, with.....per cent. added, from any sum or sums due or to become due the Contractor under this agreement.

Annulment Without Fault of Contractor.

34. (a) The Company shall have the right at any time, for reasons which appear good to it, to annul this contract upon giving thirty (30) days' notice in writing to the Contractor, in which event the Contractor shall be entitled to the full amount of the estimate for the work done by him under the terms and conditions of this contract up to the time of such annulment, including the retained percentage. The Contractor shall be reimbursed by the Company for such expenditures as in the judgment of the Chief Engineer are not otherwise compensated for, and as are required in preparing for and moving to and from the work; the intent being that an equitable settlement shall be made with the Contractor.

Notice; How Served.

(b) Any notice to be given by the Company to the Contractor under this contract shall be deemed to be served if the same be delivered to the man in charge of any office used by the Contractor, or to his foreman or agent at or near the work, or deposited in the postoffice, postpaid, addressed to the Contractor at his last known place of business.

Removal of Equipment.

(c) In case of annulment of this contract before completion from any cause whatever, the Contractor, if notified to do so by the Company, shall promptly remove any part or all of his equipment and supplies from the property of the Company, failing which the Company shall have the right to remove such equipment and supplies at the expense of the Contractor.

Failure to Make Payments.

35. Failure by the Company to make payments at the times provided in this agreement shall give the Contractor the right to suspend work until payment is made, or at his option, after thirty (30) days' notice in writing, should the Company continue to default, to terminate this contract and recover the price of all work done and materials provided and all damages sustained, and such failure to make payments at the times provided shall be a bar to any claim by the Company against the Contractor for delay in completion of the work.

Monthly Estimate.

36. So long as the work herein contracted for is prosecuted in accordance with the provisions of this contract, and with such progress as may be satisfactory to the Chief Engineer, the said Chief Engineer will, on or about the first day of each month, make an approximate estimate of the proportionate value of the work done and of material furnished or delivered upon the Company's property at the site of the work, up to and including the last day of the previous month. The amount of said estimate, after deducting.....per cent, and all previous payments, shall be due and payable to the Contractor at the office of the Treasurer of the Company on or about the 20th day of the current month.

Acceptance.

37. The work shall be inspected for acceptance by the Company promptly upon receipt of notice that the work is ready for such inspection.

Final Estimates.

38. Upon the completion and acceptance of the work the Chief Engineer shall execute a certificate over his signature that the whole work provided for in this agreement has been completed and accepted by him under the terms and conditions thereof, whereupon the entire balance found to be due to the Contractor, including said retained percentage, shall be paid to the Contractor at the office of the Treasurer of the Company within.....days after the date of said final certificate. Before the time of payment of said final estimate the Contractor shall submit evidence satisfactory to the Chief Engineer that all payrolls, materials, bills and outstanding indebtedness in connection with this work have been paid.

REPORT OF COMMITTEE XVII—ON WOOD PRESERVATION.

EARL STIMSON, *Chairman;* E. H. BOWSER, *Vice-Chairman;*
G. M. DAVIDSON, GEORGE E. REX,
H. B. DICK, E. A. STERLING,
C. F. FORD, C. M. TAYLOR,
DR. W. K. HATT, DR. H. VON SCHRENK,
V. K. HENDRICKS, T. G. TOWNSEND,

Committee.

To the Members of the American Railway Engineering Association:

The Board of Direction assigned to your Committee the following subjects:

(1) Continue investigation of proper grouping of different timbers for antiseptic treatment.

(2) Investigate the merits of various preservatives, giving special attention to oil from water-gas tar, and to the use of refined coal-tar in creosote oil.

These subjects were assigned each to a Sub-Committee for consideration.

Three meetings of your Committee were held at the Association rooms, Chicago; the first on June 12, 1912, for the purpose of organizing and outlining the year's work, those present being Earl Stimson, Chairman; E. H. Bowser, Vice-Chairman; G. M. Davidson, C. F. Ford, T. G. Townsend, V. K. Hendricks, George E. Rex, Dr. H. von Schrenk; the second on November 13, 1912, those present being Earl Stimson, Chairman; E. H. Bowser, Vice-Chairman; George E. Rex, C. F. Ford, V. K. Hendricks, T. G. Townsend, C. M. Taylor, Dr. H. von Schrenk; the third on December 18, 1912, those present being Earl Stimson, Chairman; E. H. Bowser, Vice-Chairman; G. M. Davidson, C. F. Ford, V. K. Hendricks, T. G. Townsend, Dr. H. von Schrenk.

In addition to the subjects specifically assigned for this year's consideration by the Board of Direction, your Committee continued investigations on the following two subjects assigned in previous years, but on which no final report was made:

(3) The advisability of revising the specifications for fractionation of creosote oil.

(4) Recommend forms for the inspection of preservative processes.

(1) GROUPING OF TIMBERS FOR ANTISEPTIC TREATMENT.

In the report last year your Committee stated the fundamental principles governing the grouping of timbers for treatment. These were adopted by the Association for publication in the Manual. It was the consensus of opinion that further recommendations could not be made

until an extensive series of experiments had been conducted, which would indicate the proper practice at stated locations, and with timber from specific regions. An outline of points to be covered by experimental work in different regions was prepared and sent out to the members of the Sub-Committee on Grouping, and some investigative work has been in progress during the year. Owing, however, to the long time required to reach definite conclusions and because of the difficulty of arranging for sustained experimental work along uniform lines, no data are available which would justify changing or adding to the fundamental principles outlined last year.

Some of the best authorities express the opinion that, owing to the variations in the character of the same kind of wood in different regions, the problems of grouping must be worked out at each individual treating plant, and that statements regarding detail practice which would have general application cannot be made.

Another view of the matter, which has been expressed, is that the next step is to determine the laws governing the penetration of creosote, from which the grouping of timbers according to natural resistance may be made. As the Committee has no facilities for studies of this kind, and since the wood-preserving industry looks to the U. S. Forest Products Laboratory and other institutions devoted to technical investigations for reports along this line, it is recommended that the attention of the United States Forest Products Laboratory be called to the desirability of a study of the regional variation in wood structure by species, in reference to the absorption of preservatives.

Your Committee will continue its investigations along these lines during the coming year.

(2) THE MERITS OF PRESERVATIVES.

(a) The Use of Refined Coal Tar in Creosote Oil:

The Sub-Committee to which this subject was assigned made an exhaustive research for facts pertaining thereto upon which the Committee might base a report and definite recommendations. The result was such that the Committee was not able to reach a conclusion and is not in position at this time to present a report with recommendations to the Association.

The Committee, therefore, reports progress, and will continue the consideration of this subject.

(b) The Use of Oil from Water-Gas Tar:

So far as your Committee has been able to learn, water-gas creosote has not been extensively used under its own name as a wood preservative, and there is very little information to be found as to its efficacy.

There are a few piles treated with it and driven in the harbor at Norfolk, Va. These waters are badly infested with Teredo, and the piles are said not to have been attacked, although they have been there about

three years. Professor Alleman has a tie at Swarthmore which was treated with water-gas creosote and was in service nine years at Porto Rico. This tie is still sound. The Public Service Corporation of New Jersey has been using water-gas creosote for several years for treating ties. These ties should show in about two years whether the treatment is good or not. They are now treating a large number of pine ties with straight water-gas creosote furnished by the United Gas Improvement Company of Philadelphia. One of the large creosoting companies has recently obtained a patent for treating wood with a mixture of water-gas creosote and coal-tar creosote, and one of the large railroad companies is contemplating the use of a mixture of water-gas creosote and coal-tar creosote for ties. The United States Forest Service has some specimens treated with water-gas creosote placed at West Pascagoula and Gulfport, Miss.; the latter put in the water in March, 1912. None of the specimens has been there long enough to give any results.

It seems that the principal objection to water-gas creosote has been to its unauthorized use as an adulterant in coal-tar creosote. Its use, however, is now increasing in legitimate mixtures, and, while it is too early to get any results, it seems that a number of people favor using at least a mixture of this oil with coal-tar creosote.

It is recommended that the investigation of this subject be continued for another year.

(3) CONSIDERATION OF THE SPECIFICATIONS FOR FRACTIONATION OF CREOSOTE OIL.

For some years past your Committee has had under consideration the relative merits of the flask and retort for the fractionation of creosote oil. For the purpose of obtaining information on this point, and on which to base consideration of further revisions in the specifications for fractionation, your Committee sent samples of various creosote oils to different railroads for fractionation by the various methods. A full statement, including charts and tables of results of these fractionations is presented as Appendix "A" to this report. Based thereon, your Committee recommends that no change be made in the adopted specifications for fractionation of creosote oil.

(4) FORMS FOR REPORTING INSPECTION.

Two forms for reporting inspection of treatment are submitted. Form "A" provides a record of the treatment and the determination of the absorption of the preservative by gage readings. Form "B" provides a record of the determination of the absorption by weighing.

These forms are intended as a general guide for reporting and keeping records of the inspection of the treatment of timbers, and may be varied to suit any special kind of treatment.

The following is explanatory of the gage readings, designated by letter on Form "A":

Reading "A"—Is the reading of the measuring tank gage before the oil is put into the cylinder.

Reading "B"—Is the tank gage reading when the cylinder is completely filled.

Reading "C"—Is the tank gage reading when the pumping of the oil into the cylinder is stopped.

Reading "D"—Is the tank gage reading after all the oil from the charge is returned to the measuring tank.

Reading "A" minus "D," corrected for temperatures, gives the number of gallons used in the charge.

Reading "B" minus "C" gives the number of gallons pumped into the timber after the cylinder is filled and is used to give the gross absorption for light processes where oil is taken out of the timber by an initial air pressure, or by a final vacuum, or both. There will be a discrepancy in this gross absorption, due to the amount of oil absorbed by the timber while cylinder is being filled.

RECORDS FROM SERVICE TESTS.

As Appendix "B" to this report will be found the Record from Service Tests, brought up to date and extended to include a number of additional tests not shown on the records submitted with the report of last year.

CONCLUSIONS.

It is recommended:

(1) That no change be made in the adopted Specifications for the Fractionation of Creosote Oil.

(2) That the forms "A" and "B" for reporting the Inspection of Treatment of Timbers, and the notes explanatory of the gage readings on Form "A," as given under sub-head four (4), "Forms for Reporting Inspection," be adopted for insertion in the Manual.

OUTLINE OF WORK FOR 1913.

Your Committee recommends:

(1) Continue investigations of the merits as a preservative of oil from water-gas and the use of refined coal-tar in creosote oil.

(2) Continue the compilation of available information from Service Tests.

(3) Continue the investigation of the proper grouping of the different timbers for antiseptic treatment.

(4) Report on methods of accurately determining the absorption of creosote oil.

(5) That the Board of Direction assign the work of drawing up a Standard Specification for Timber for Treatment to a Joint Committee of the Committee on Wood Preservation and the Committee on Grading of Lumber.

Respectfully submitted,

COMMITTEE ON WOOD PRESERVATION.

FORMS FOR REPORTING INSPECTION.

Form A.

_____
(Name of Railroad)

_____ Department

_____ Plant

_____ Inspector

Date														
Kind of Treatment														
Retort Number														
Charge Number														
Liquid Used														
% of Chloride														
Steam or Air Admitted														
Vacuum Applied														
Liquid Admitted														
Pump Started														
Treatment Ended														
Steam or Air Pressure, Lbs.														
Vacuum, Inches														
Pressure of Liquid, Lbs.														
Measuring Tank Number														
Gallons per Tank Foot														
Reading A														
Temperature A. Degrees Fahr.														
Reading B.														
Temperature B. Degrees Fahr.														
Reading C.														
Temperature C. Degrees Fahr.														
Reading D.														
Temperature D Degrees Fahr.														
Gallons Pumped Into Timber per Charge B-C														
Gallons Pumped Into Timber per Tie.														
Pounds Pumped Into Timber per Cu. Ft.														
Total Gals. Used 100 F. A-D														
Gals. per Cu. Ft. of Timber.														
Gals. per Tie.														
Lbs. per Cu. Ft. of Timber														
Lbs. of Chloride Per Cu. Ft. Timber.														
Material Treated														

Form B.

Date _____ (Name of Railroad) Date _____

Kind of Treatment _____ _____ Plant Kind of Treatment _____

Run No. _____ Kind of Timber _____ Kind of Timber _____ Run No. _____

Tram Number	No. of Ties	Gross Weight Before Treatment	Weight of Tram	Weight of Ties Before Treatment	Gross Weight After Treatment	Weight of Ties After Treatment	Gain Per Tie

_____ Inspector

Lbs. of Oil Per Tie _____ % of Chloride in Solution _____

Total Gals. Oil @ 100° Fahr. _____ Total Lbs Liquid Used _____

Gals. Absorbed per Tie _____ Lbs. Chloride per Tie _____

Tram Number	No. of Ties	Gross Weight Before Treatment	Weight of Tram	Weight of Ties Before Treatment	Gross Weight After Treatment	Weight of Ties After Treatment	Gain Per Tie

_____ Inspector

Lbs. of Oil Per Tie _____ % of Chloride in Solution _____

Total Gals. Oil @ 100° Fahr. _____ Total Lbs. Liquid Used _____

Gals. Absorbed per Tie _____ Lbs. Chloride per Tie _____

Appendix A.

CONSIDERATION OF THE SPECIFICATIONS FOR FRACTIONATION OF CREOSOTE OIL.

It has been noted from time to time that in making fractional distillations of creosote oil, the results of these fractions, when made by different operators, differ considerably. In using the present standard method of fractionation, it was suggested that better results might possibly be obtained by using a flask instead of the retort. In order to determine whether any such improvement might be obtained, the Committee carried out a long series of determinations during the past year. Two distinctly different samples of creosote oil, marked respectively "A" and "B," were sent to various members of the Committee, with the request that these be analyzed in two different ways, the one by using the present standard method of fractionation, and the other by using a side-neck flask, in which the outlet tube was located in the neck of the flask, just above the body of the flask. The thermometer was placed half an inch above the surface of the oil in the distillation just as in the retort analysis. Each operator was requested to make a number of analyses of the same oil, using the two different methods. The results of the examinations are given in the following tables and they are also charted graphically in the following tables. The various railroads making the examinations are marked by numbers, and where more than one operator made analyses for any one railroad, these operators are designated by letters. In the tables and charts "A" represents one and the same creosote oil, and "B" represents the second creosote oil.

ANALYSES OF CREOSOTE OIL BY RAILROAD NO. 1.

Oil "A"—Retort.

Number	1	2	3	4	5	6
Specific Gravity at 15° C.	1.047	.....	.....	.....	.....	.....
Water	1.3%	.....	.....	.....	.....	.....
Distillation:						
Below 200° C.	5.1%	4.3%	4.3%	5.3%	4.9%	5.5%
200 to 210 "	7.0	7.5	6.8	6.9	7.8	7.2
210 to 235 "	38.7	38.3	39.8	39.7	39.4	39.7
235 to 270 "	23.5	22.8	22.4	23.3	22.6	21.9
270 to 315 "	11.3	12.5	11.4	11.0	10.8	12.0
315 to 355 "	9.3	8.8	9.5	8.4	9.6	9.0
Residue	5.1	5.8	5.8	5.4	4.9	4.7

Oil "A"—Flask.

Below 200° C.	4.0%	3.0%	2.8%	3.1%	4.2%	4.0%
200 to 210 "	4.4	4.8	6.6	5.0	5.9	4.9
210 to 235 "	38.6	39.6	38.2	39.3	38.8	37.8
235 to 270 "	26.2	25.7	25.1	24.7	25.0	26.1
270 to 315 "	11.7	10.9	11.2	12.1	11.6	10.8
315 to 355 "	8.4	9.0	9.3	9.7	8.6	9.7
Residue	6.7	7.0	6.8	6.1	5.9	6.7

Oil "B"—Retort.

Number	1	2	3	4	5	6
Specific Gravity	1.081	.....	.....	.....	.....	.....
Water	None	.....	.....	.....	.....	.....
Distillation:						
Below 200° C.	0.0%	0.7%	1.2%	0.6%	1.1%	0.7%
200 to 210 "	1.6	0.7	0.6	1.0	0.8	1.0
210 to 235 "	11.0	12.3	11.5	12.0	10.5	11.7
235 to 270 "	21.2	22.1	21.8	22.9	22.3	21.3
270 to 315 "	23.4	23.0	23.9	23.2	24.1	24.0
315 to 355 "	25.6	24.9	24.4	24.7	25.2	25.5
Residue	17.2	16.3	16.6	15.6	16.0	15.8

Oil "B"—Flask.

Below 200° C.	0.6%	0.2%	0.8%	1.0%	0.7%	0.4%
200 to 210 "	1.0	0.6	0.6	0.5	0.5	0.5
210 to 235 "	7.4	8.0	8.6	8.9	8.7	8.0
235 to 270 "	23.5	23.9	22.6	22.8	23.0	22.7
270 to 315 "	24.5	23.6	23.9	23.7	23.5	24.0
315 to 355 "	25.4	26.7	26.1	24.9	25.7	25.4
Residue	17.6	17.0	17.4	18.2	17.9	19.0

ANALYSES OF CREOSOTE OIL BY RAILROAD NO. 2.

Oil "A"—Retort.

Analysis Number	1	2	3	4	5	6
Specific Gravity	1.025	1.025	1.033	1.033	1.033	1.033
Water	1.98%	1.91%	1.00%	1.50%	1.25%	1.00%
Fractionation:						
Below 200° C.	4.21%	4.44%	2.73%	2.74%	3.08%	2.93%
200 to 210 "	8.62	7.75	6.86	5.58	6.07	5.75
210 to 235 "	40.69	41.42	40.60	40.69	42.83	40.88
235 to 270 "	22.99	21.94	22.70	24.46	21.16	21.41
270 to 315 "	10.86	10.41	10.60	9.64	12.05	11.90
315 to 355 "	7.79	9.47	9.40	9.60	7.69	9.09
Residue	4.75	5.65	6.56	5.32	6.07	6.56

Oil "A"—Flask.

Analysis Number	1	2	3	4	5	6
Specific Gravity	1.025	1.025	1.025	1.025	1.025	1.025
Water	1.95%	1.98%	1.97%	1.90%	1.89%	1.74%
Fractionation:						
Below 200° C.	3.15%	3.60%	3.55%	3.36%	3.11%	3.09%
200 to 210 "	7.04	6.72	6.13	7.56	6.81	6.13
210 to 235 "	39.67	37.02	40.15	37.54	39.01	37.91
235 to 270 "	24.33	26.66	24.30	23.63	24.35	27.31
270 to 315 "	12.03	12.82	12.77	12.41	13.87	12.24
315 to 355 "	8.67	7.63	7.50	8.17	7.41	8.70
Residue	5.06	5.05	5.04	5.63	5.00	4.51

Oil "B"—Retort.

Analysis Number	1	2	3	4	5	6
Specific Gravity	1.064	1.064	1.064	1.064	1.065	1.066
Water	Trace	Trace	Trace	Trace	Trace	Trace
Fractionation:						
Below 200° C.	0.20%	0.30%	0.40%	0.20%	0.50%	0.20%
200 to 210 "	0.85	0.90	0.70	0.85	0.90	0.90
210 to 235 "	10.00	10.30	10.10	10.02	10.50	11.40
235 to 270 "	24.50	25.40	24.30	24.00	24.80	25.50
270 to 315 "	23.50	22.40	22.20	22.40	22.30	23.50
315 to 355 "	24.80	25.10	26.80	26.00	25.70	24.40
Residue	14.70	14.00	14.40	16.20	14.50	13.60

Oil "B"—Flask.

Analysis Number	1	2	3	4	5	6
Specific Gravity	1.0625	1.0625	1.0625	1.0625	1.0625	1.065
Water	Trace	Trace	Trace	Trace	Trace	Trace
Fractionation:						
Below 200° C.	0.39%	0.38%	0.74%	0.28%	0.38%	0.50%
200 to 210 "	0.54	0.48	0.43	0.64	0.48	0.40
210 to 235 "	10.51	9.75	10.07	9.70	9.47	9.40
235 to 270 "	23.81	23.23	25.25	25.99	26.36	24.10
270 to 315 "	26.42	26.67	24.25	25.52	25.56	24.30
315 to 355 "	25.05	25.45	27.31	25.65	23.34	26.00
Residue	13.69	13.54	11.71	11.88	14.31	14.40

ANALYSES OF CREOSOTE OIL BY RAILROAD NO. 3.

Oil "A."

	Side Neck Flask.		—Retort.—	
Analysis Number	1	2	1	2
Specific Gravity	1.0149	.....	.....	.....
Water	0.30%	.....	.....	.....
Fractionation:				
Below 200° C.	4.33%	4.25%	7.52%	5.95%
200 to 210 "	5.85	6.06	7.99	8.70
210 to 235 "	37.66	37.73	38.69	38.32
235 to 270 "	25.17	25.42	16.57	18.13
270 to 315 "	11.97	9.65	11.80	12.06
315 to 355 "	6.85	7.74	6.84	6.00
Residue	8.17	9.15	10.59	10.84

Residue remained soft.

Rate of distillation, about two drops per second.

Oil "B."

	Side Neck Flask.		—Retort.—	
Analysis Number	1	2	1	2
Specific Gravity	1.0812	.....	.....	.....
Water	0.50%	.....	.....	.....
Fractionation:				
Below 200° C.	0.56%	0.68%	1.15%	1.01%
200 to 210 "	2.04	2.01	2.54	2.34
210 to 235 "	11.47	11.90	18.56	16.41
235 to 270 "	23.86	22.12	17.15	16.46
270 to 315 "	17.60	16.44	21.01	20.90
315 to 355 "	3.33	4.13	5.19	5.82
Residue	42.14	42.72	34.40	36.06

Residue remained soft.

Rate of distillation, about two drops per second; somewhat faster.

ANALYSES OF CREOSOTE OIL BY RAILROAD NO. 5.

OPERATOR M.

	Oil "A" Retort.	Oil "A" Flask.
Analysis Number	1	1
Specific Gravity	1.041	1.041
Water	0.7%	0.6%
Fractionation:		
Below 200° C.	4.1%	3.1%
200 to 210 "	6.0	5.4
210 to 235 "	40.4	42.8
235 to 270 "	22.3	21.65
270 to 315 "	12.2	11.85
315 to 355 "	8.3	8.1
Residue	6.7	7.1

Oil "B"—Retort.

Analysis Number	1	2	3	4	5
Specific Gravity	1.069	1.0688	1.0688	1.0686	1.0686
Water	Trace	Trace			
Fractionation:					
Below 200° C.	.2%	.3 %	.5 %	.8 %	.2 %
200 to 210 "	1.1	1.0	.7	.9	1.0
210 to 235 "	11.6	11.15	10.1	10.15	10.35
235 to 270 "	23.3	23.45	24.85	23.2	23.00
270 to 315 "	23.3	23.35	23.05	23.5	23.55
315 to 355 "	22.3	22.25	22.65	22.05	22.20
Residue	18.2	18.5	18.15	19.4	19.70

Oil "B"—Flask.

Analysis Number	1	2	3	4
Specific Gravity	..	..	..	..
Water	Trace	Trace	.....	.....
Fractionation:				
Below 200° C.	...	...	...	...
200 to 210 "	.4%	.4%	.3%	.2 %
210 to 235 "	8.9	9.1	9.2	8.8
235 to 270 "	24.3	22.7	23.5	23.55
270 to 315 "	25.5	24.8	23.8	24.25
315 to 355 "	21.4	23.2	23.5	22.4.
Residue	19.5	19.8	19.7	20.8

ANALYSES OF CREOSOTE OIL BY RAILROAD NO. 5.

OPERATOR S.

Oil "A"—Retort.

Analysis Number	1	2	3	4	5	6
Specific Gravity	1.036	1.035	..	..	..	..
Water	1.2%	1.2%	1.1%	1.2%	1.0%	1.0%
Fractionation:						
Below 200° C.	4.8%	4.6%	4.4%	4.2%	3.9%	3.6%
200 to 210 "	9.8	9.7	9.8	9.2	8.6	8.1
210 to 235 "	38.9	38.9	38.8	38.6	39.6	39.8
235 to 270 "	19.8	20.2	20.8	21.5	21.6	21.8
270 to 315 "	12.6	11.4	12.2	11.8	12.4	12.5
315 to 355 "	10.1	15.2	10.4	14.7	13.9	14.2
Residue	4.0	15.2	3.6	14.7	13.9	14.2

Oil "A"—Flask.

Analysis Number	7	8	9	10	11	12
Specific Gravity	1.035	..	..	..	..	..
Water	0.8%	0.9%	1.1%	1.0%	1.2%	1.1%
Fractionation:						
Below 200° C.	2.2%	2.1%	2.7%	1.9%	2.1%	2.4%
200 to 210 "	6.2	6.0	5.5	5.2	5.0	5.0
210 to 235 "	39.2	39.7	39.9	39.9	39.9	39.0
235 to 270 "	24.3	25.0	24.0	25.0	24.7	25.7
270 to 315 "	12.7	12.5	12.6	12.5	12.4	12.6
315 to 355 "	9.9	9.5	9.7	9.9	9.8	9.2
Residue	5.5	5.2	5.6	5.6	6.1	6.1

ANALYSES OF CREOSOTE OIL BY RAILROAD NO. 5.

OPERATOR S.

Oil "B"—Retort.

Analysis Number	13	14	15	16	17	18
Specific Gravity	1.069	..	..	..	..	..
Water	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Fractionation:						
Below 200° C.	.6%	.4%	.5%	.5%	.6%	.5%
200 to 210 "	.5	.8	.8	.9	.8	.5
210 to 235 "	9.8	10.4	11.2	10.0	10.9	9.2
235 to 270 "	24.2	24.2	24.4	26.2	25.0	26.0
270 to 315 "	24.9	25.4	24.3	23.8	24.3	25.0
315 to 355 "	26.2	25.0	25.5	25.1	25.8	25.5
Residue	13.8	13.8	13.3	13.5	12.6	13.2

Oil "B"—Flask.

Analysis Number	19	20	21	22	23	24
Specific Gravity	1.069	1.068	..	..	..	..
Water	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Fractionation:						
Below 200° C.	.5%	.4%	.2%	.3%	.2%	.3%
200 to 210 "	.6	.6	.7	.5	.5	.6
210 to 235 "	9.0	9.3	9.0	9.0	8.6	9.0
235 to 270 "	22.5	22.4	23.2	22.0	23.5	22.2
270 to 315 "	22.8	22.6	22.7	22.5	25.2	22.4
315 to 355 "	26.1	26.7	25.8	26.4	26.7	26.5
Residue	18.5	18.4	18.8	19.3	15.3	19.0

ANALYSES OF CREOSOTE OIL BY RAILROAD NO. 6.

OPERATOR R.

Oil "A"—Retort.

Analysis Number	1	2	3	4	5	6
Specific Gravity	1.048	..	..	..	..	..
Water	1.7%	..	..	..	..	..
Fractionation:						
Below 200° C.	5.5%	5.8%	6.0%	5.0%	5.8%	5.0%
200 to 210 "	9.3	7.0	8.4	9.2	7.4	9.7
210 to 235 "	38.4	38.6	40.4	40.7	40.8	39.8
235 to 270 "	19.9	20.7	20.0	20.8	21.9	19.6
270 to 315 "	11.8	12.7	11.0	10.5	11.0	11.0
315 to 355 "	8.9	8.6	8.0	8.7	8.2	9.4
Residue	5.9	6.0	5.3	5.0	5.0	5.3

Oil "A"—Flask.

Below 200° C.	2.0%	3.6%	3.0%	2.9%	2.1%	2.5%
200 to 210 "	4.1	4.1	4.7	5.6	4.0	4.8
210 to 235 "	40.5	40.4	39.9	38.2	40.7	40.9
235 to 270 "	25.2	25.7	25.9	25.2	25.2	24.4
270 to 315 "	12.0	11.7	12.0	12.0	11.9	12.9
315 to 355 "	9.4	9.1	9.1	9.1	9.6	9.1
Residue	6.6	5.4	5.4	6.1	5.5	5.2

Oil "B"—Retort.

Analysis Number	1	2	3	4	5	6
Specific Gravity	1.0828	..	..	..	..	..
Fractionation:						
Water	Trace	..	..	..	..	..
Below 200° C.	.9%	.8%	1.0%	1.1%	.6%	1.3%
200 to 210 "	1.0	.9	0.8	1.0	1.6	1.2
210 to 235 "	12.9	11.0	11.9	11.4	12.5	12.4
235 to 270 "	22.5	23.2	24.0	21.9	22.4	22.3
270 to 315 "	23.3	23.9	24.0	24.6	23.9	24.3
315 to 355 "	25.3	25.1	23.4	25.4	24.2	23.5
Residue	14.3	14.7	14.9	14.1	15.2	14.7

Oil "B"—Flask.

Below 200° C.	.7%	.4%	.3%	.3%	.4%	.3%
200 to 210 "	.4	.6	.6	.5	.6	.4
210 to 235 "	7.8	8.3	9.8	8.6	8.5	8.0
235 to 270 "	23.9	22.9	21.5	22.5	23.3	23.2
270 to 315 "	23.7	23.7	24.4	24.5	23.7	23.7
315 to 355 "	24.8	25.4	26.0	25.8	26.1	26.6
Residue	18.2	18.4	18.1	17.9	17.7	18.0

Specific Gravity at 15° C.

ANALYSES OF CREOSOTE OIL BY RAILROAD NO. 6.

OPERATOR B.

Oil "A"—Retort.

Analysis Number	1	2	3	4	5	6	Av.
Specific Gravity	1.048	..	..	..	..	..	..
Water	1.25%	..	..	..	..	..	..
Fractionation:							
Below 200° C.	3.8%	5.6%	4.6%	3.7%	3.8%	3.9%	4.2%
200 to 210 "	5.4	6.0	6.2	5.2	7.1	6.3	6.0
210 to 235 "	42.7	40.5	42.2	41.8	40.6	40.6	41.4
235 to 270 "	25.1	24.9	23.4	24.1	23.0	24.9	24.2
270 to 315 "	10.9	12.6	10.4	11.4	12.6	11.5	11.6
315 to 355 "	7.9	5.9	7.6	7.8	7.6	7.6	7.4
Residue	5.1	4.3	5.6	6.0	4.9	5.7	5.3

Oil "A"—Flask.

Below 200° C.	2.7%	2.6%	3.1%	2.0%	2.6%	2.8%	2.6%
200 to 210 "	4.5	4.3	4.1	5.0	4.7	4.6	4.5
210 to 235 "	40.8	41.2	40.3	39.8	41.3	41.0	40.7
235 to 270 "	24.2	24.0	25.3	25.5	24.9	24.8	24.8
270 to 315 "	12.9	12.8	11.9	12.2	11.6	12.1	12.2
315 to 355 "	7.8	9.0	9.0	8.5	8.9	9.0	8.7
Residue	6.8	6.5	6.3	6.6	6.3	6.3	6.4

Oil "B"—Retort.

Analysis Number	1	2	3	4	5	6	Av.
Specific Gravity	1.083	..	..	..	..	..	..
Water	Few drops	..	..	..	..	..	..
Fractionation:							
Below 200° C.	.3%	.5%	.3%	.4%	.4%	.3%	.4%
200 to 210 "	1.2	1.0	1.0	.6	1.0	.6	.9
210 to 235 "	9.0	7.8	10.6	8.3	9.7	8.6	9.0
235 to 270 "	26.1	26.5	23.7	25.8	23.9	25.3	25.2
270 to 315 "	23.9	25.7	24.4	24.6	24.8	24.3	24.6
315 to 355 "	24.1	24.4	24.2	23.8	23.7	24.2	24.1
Residue	15.0	14.9	15.8	16.5	16.5	16.6	15.9

Oil "B"—Flask.

Below 200° C.	.1%	.1%	.4%	.0%	.0%	.2%	.1%
200 to 210 "	.8	.7	.9	.2	.6	.6	.8
210 to 235 "	8.0	7.7	6.9	6.9	6.3	7.1	7.1
235 to 270 "	22.4	22.0	23.4	23.8	24.9	23.5	23.3
270 to 315 "	24.6	24.9	23.9	24.0	23.4	23.9	24.1
315 to 355 "	25.9	26.6	26.7	26.7	26.5	26.5	26.5
Residue	17.8	17.8	17.2	17.4	18.0	17.8	17.7

Specific Gravity at 15° C.

ANALYSES OF CREOSOTE OIL BY RAILROAD NO. 7.

Oil "A"—Retort.

Analysis Number	1	2	3
Specific Gravity at 15° C.	1.0486	1.0486	1.0486
Water	1.0%	1.0%	1.0%
Fractionation:			
Below 200 C°	2.93%	2.83%	3.94%
200 to 210 "	4.55	3.84	3.84
210 to 235 "	38.18	38.09	39.00
235 to 270 "	24.85	26.87	25.55
270 to 315 "	12.42	11.92	10.10
315 to 335 "	5.25	4.95	5.25
Residue	10.91	10.70	12.02

Distillation stopped at 335° C.

Oil "A"—Flask.

Below 200° C.	1.21%	1.92%	1.72%
200 to 210 "	.60	1.61	1.62
210 to 235 "	28.78	33.20	31.11
235 to 270 "	36.46	31.50	34.64
270 to 315 "	14.54	12.70	12.52
315 to 355 "	10.40	11.60	11.52
Residue	7.07	7.10	6.87

Oil "B"—Retort.

Analysis Number	1	2	3
Specific Gravity at 15° C.	1.0828	1.0828	1.0828
Water	Trace	Trace	Trace
Fractionation:			
Below 200° C.	1.3%	1.5%	1.3%
200 to 210 "	.4	.5	.5
210 to 235 "	5.2	5.4	5.6
235 to 270 "	22.2	22.0	22.2
270 to 315 "	20.2	21.6	20.4
315 to 355 "	26.1	24.0	24.5
Residue	24.6	25.1	25.5

Oil "B"—Flask.

Below 200° C.	0.00%	0.00%	0.00%
200 to 210 "	1.10	0.90	0.80
210 to 235 "	4.40	4.60	5.10
235 to 270 "	20.60	21.20	21.80
270 to 315 "	21.40	20.60	22.10
315 to 355 "	21.50	25.90	22.60..
Residue	31.30	25.80	27.70

A careful study of the results shows that there are variations in the methods of fractionation in both cases, due largely to varying conditions under which the fractionations are made, such as the rate of fractionation, the kind of heat application used, and the care and attention of the operator. It will be noted, as regards the fluctuations of the fractionations made by one operator with the same oil, that the fluctuations in the results obtained when using the flask were just as large as when the retort was used. It will also be noted that the variations obtained, when comparing the results of analyses made by different operators, using the flask in one case and the retort in the other, were in many instances greater than the variations obtained when comparing the results of the analyses by the same operator using the retort in one case and the flask in the other. The results of the two sets of analyses show, when one and the same oil is used, that the flask usually shows a lower percentage of low boiling compounds in any oil than is shown when this

same oil is analyzed by using the retort; that is, the flask analysis makes the oil appear a better oil than does the retort analysis.

After a careful study of the results, the Committee finds the following:

The results obtained when using the flask method of analysis do not give any better results than when the present standard method (using the retort) is employed. In view of the fact that the present standard method has been more or less universally adopted in contracts for creosote oil and in railroad specifications, and in view of the above findings as to accuracy of results, the Committee feels that no change should be made in the present method of fractionation of coal-tar creosote.

PRESERVATION.

AILROAD NO. 2.

DISTILLATIONS.

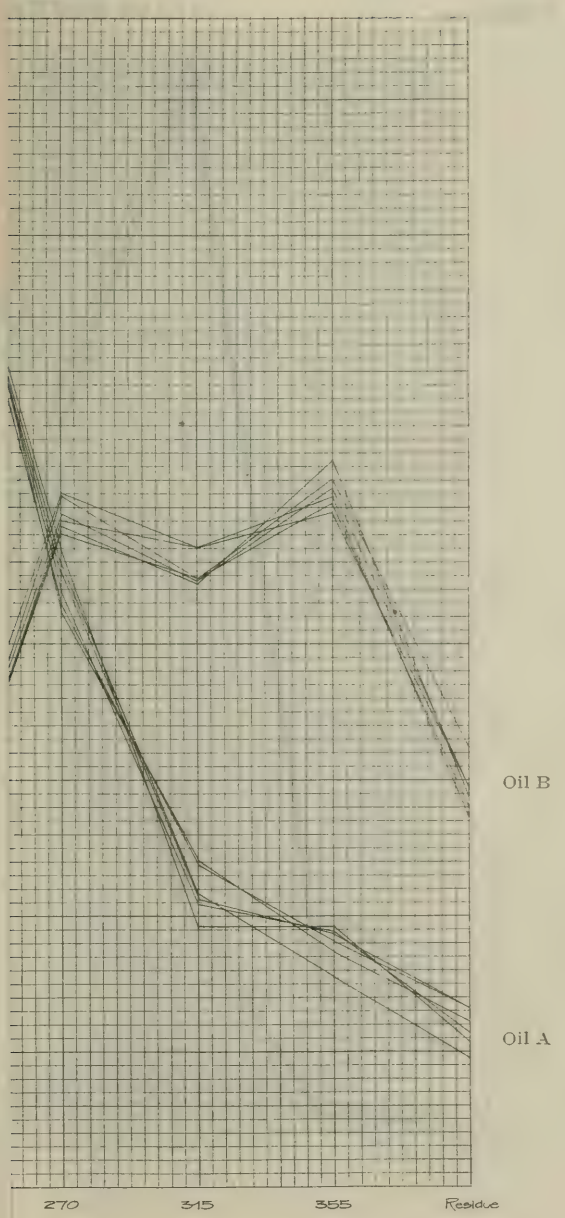


PLATE XCI

RETORT DISTILLATIONS

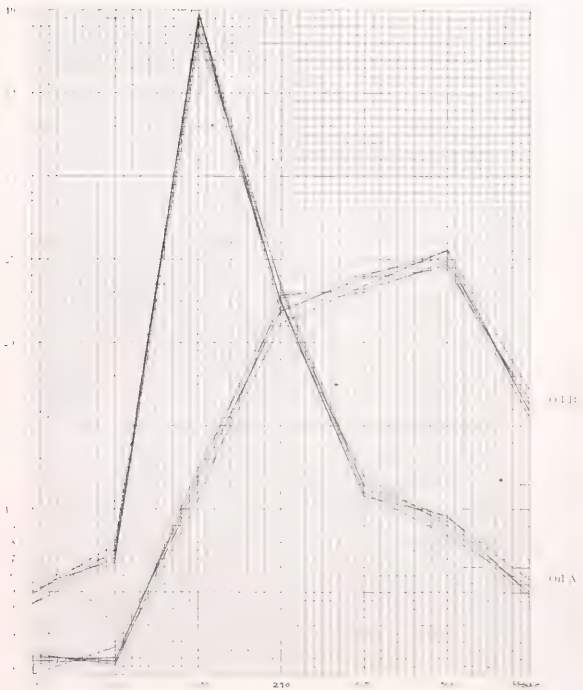
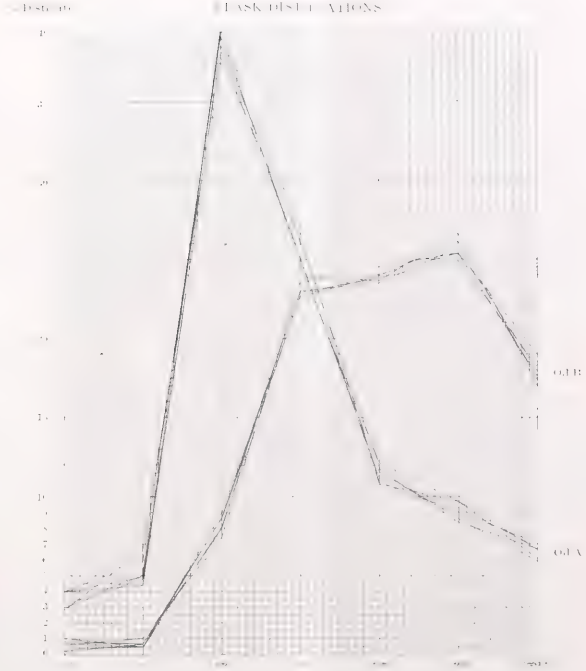


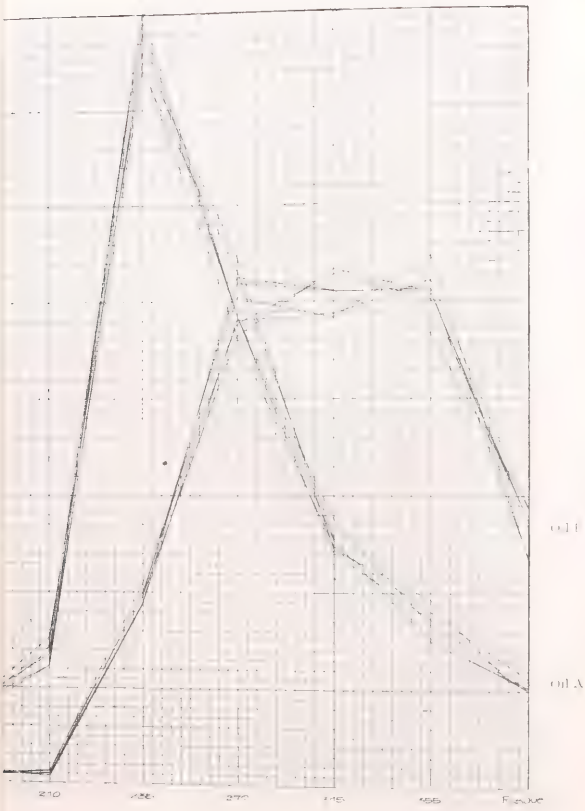
PLATE XCI

FLASK DISTILLATIONS



RAILROAD No. 2

FLASK DISTILLATIONS.

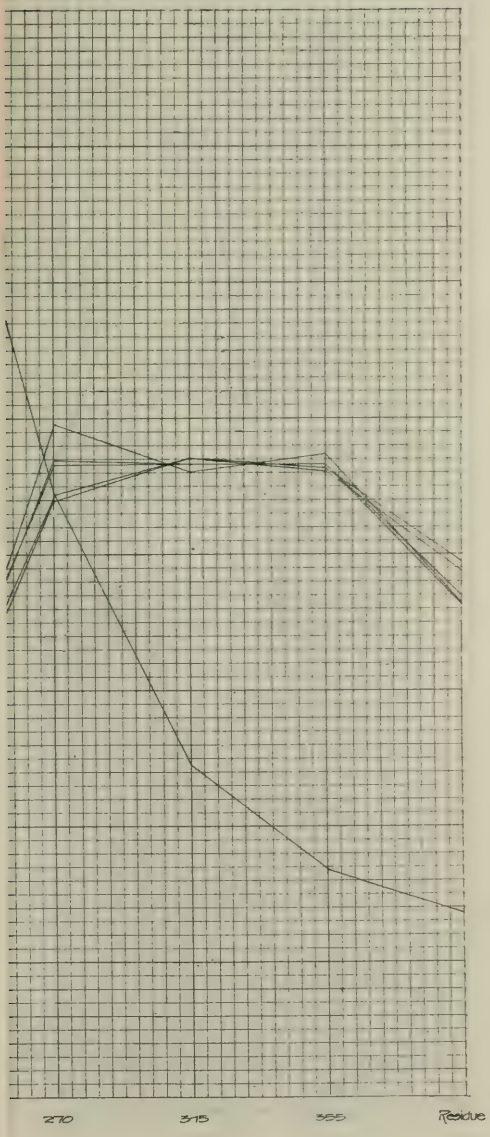


PRESERVATION.

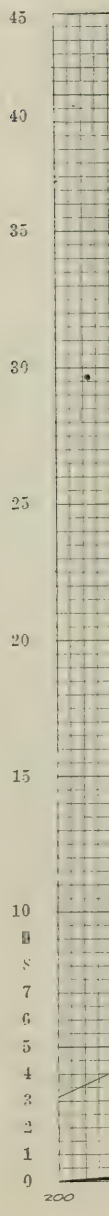
ILROAD NO. 5.

PERATOR M.

DISTILLATIONS.



% Distillates



RETORT DISTILLATIONS

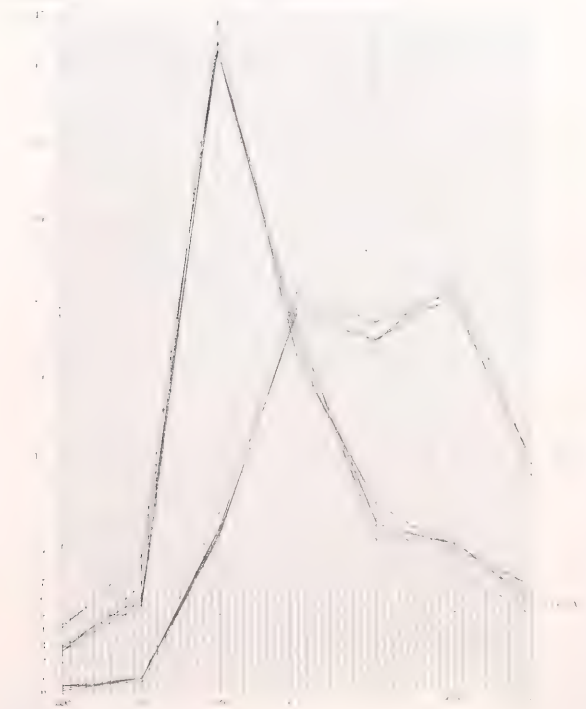
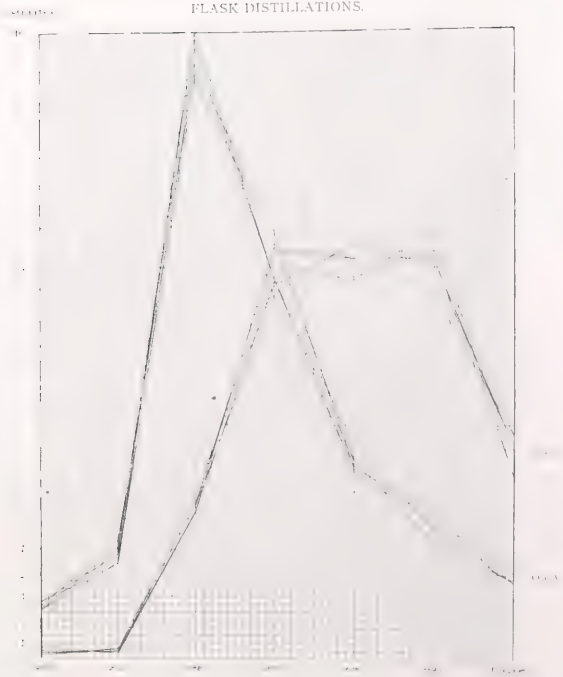
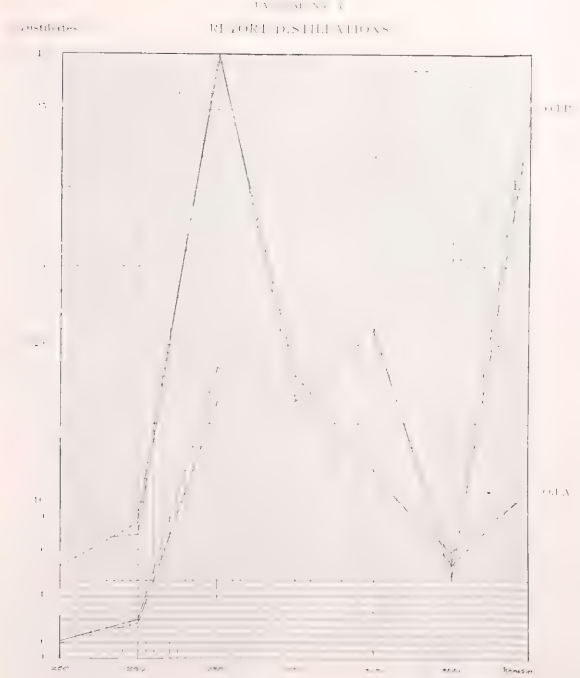
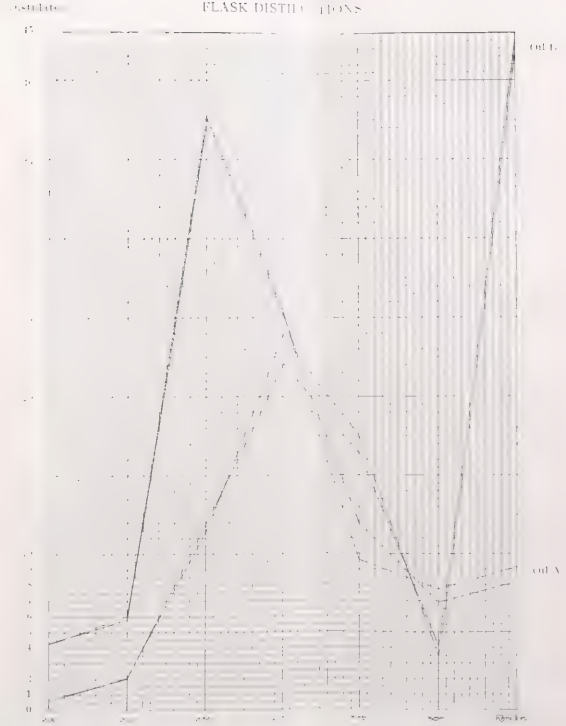


PLATE X. No. 2

FLASK DISTILLATIONS.

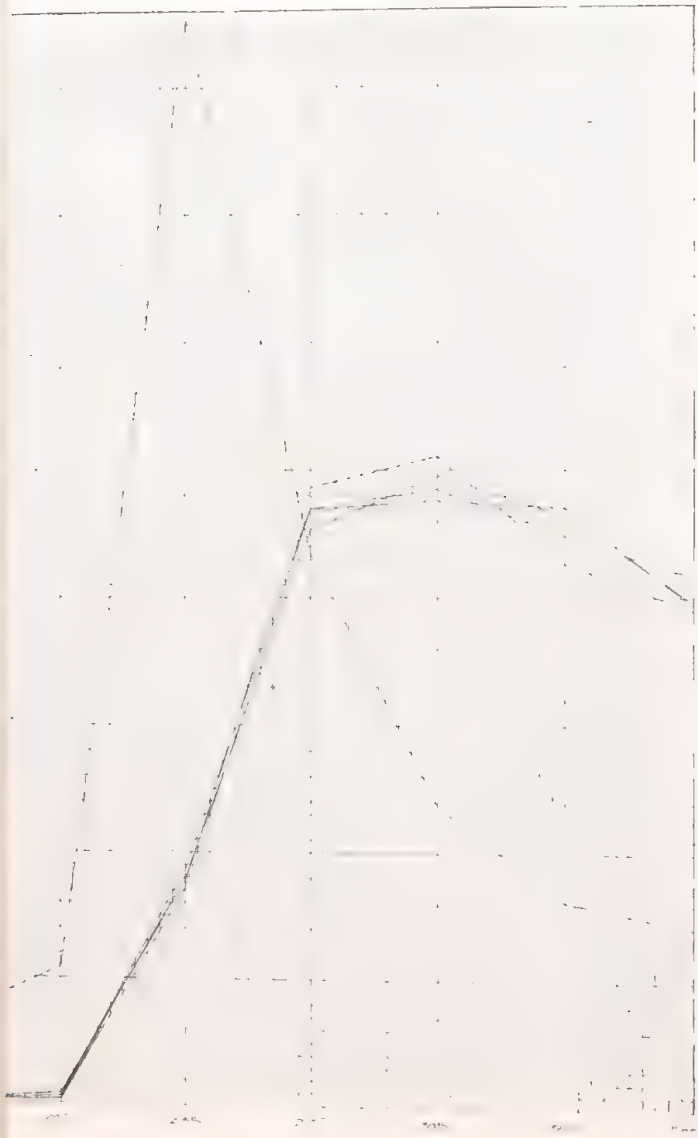



Distillate
REFORE DISTILLATIONS
OIL P
OIL A


Distillate
FLASK DISTILLATIONS
OIL L
OIL A

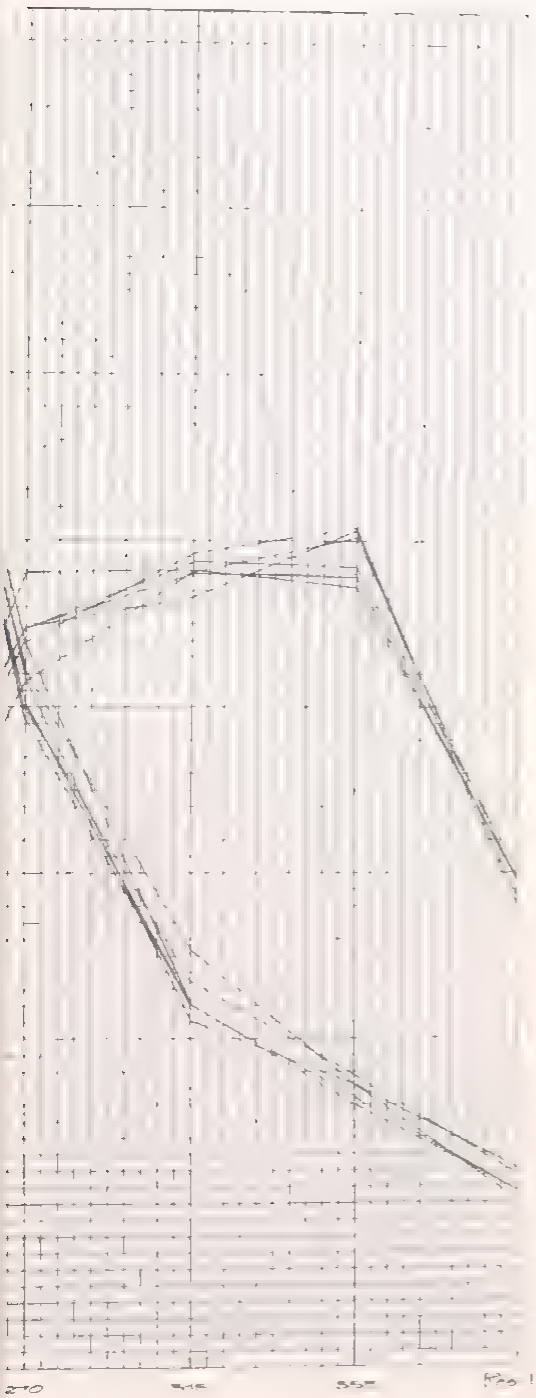
APPENDIX M

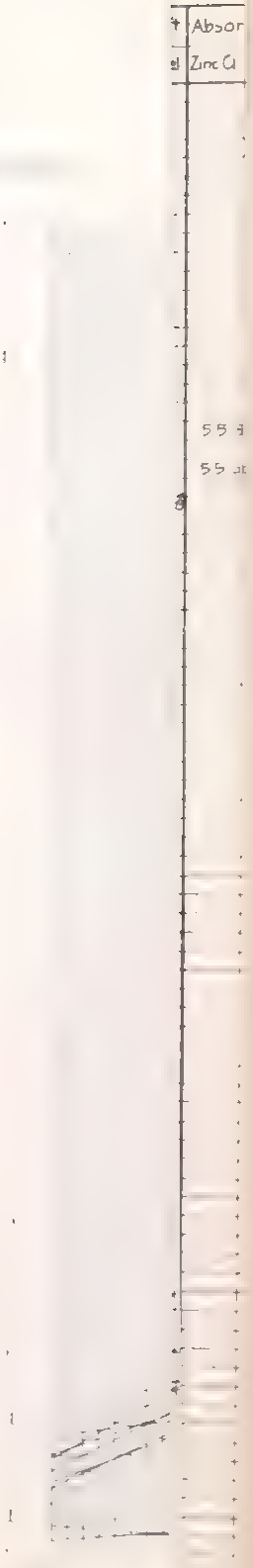
TEST OBSERVATIONS



LSERVATION

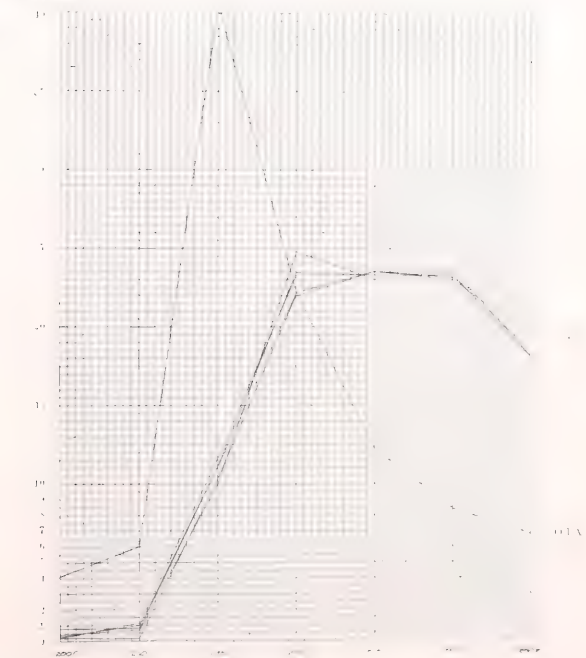
OBSERVATIONS





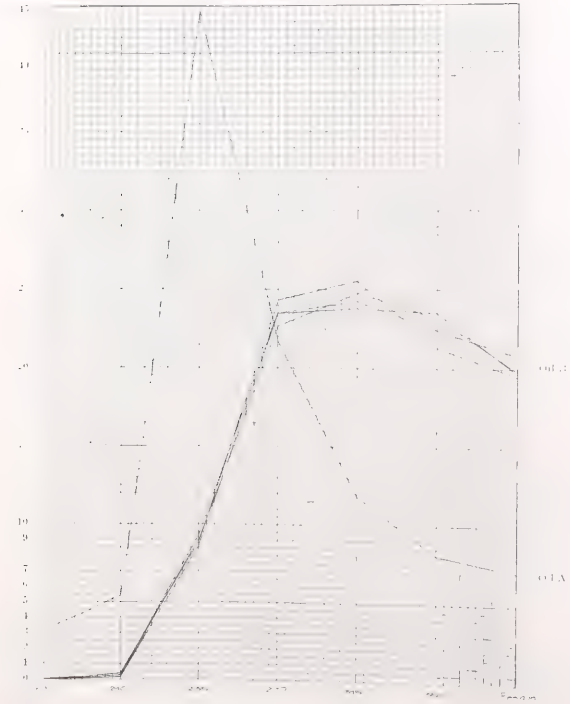
WOOD PRESERVATION

RETORT DISTILLATIONS



WOOD PRESERVATION

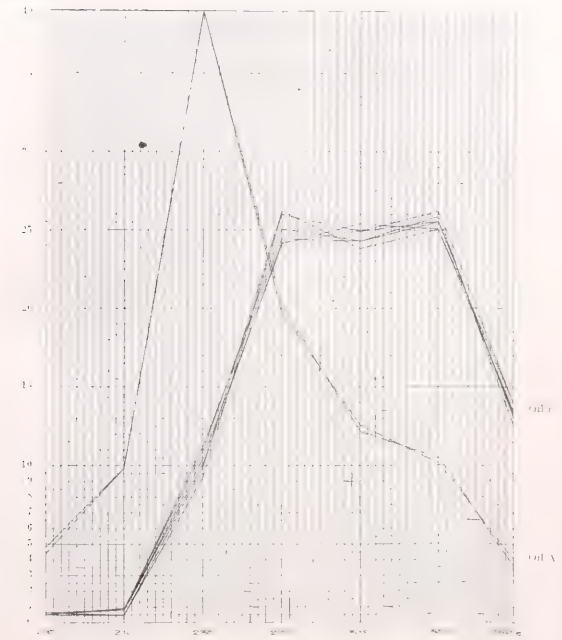
FLASK DISTILLATIONS.



WOOD PRESERVATION

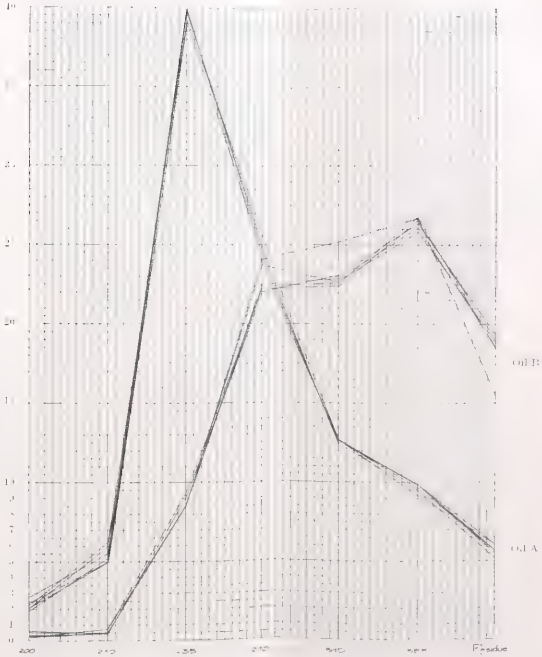
OPERATOR S.

RETORT DISTILLATIONS.



WOOD PRESERVATION

FLASK DISTILLATIONS.

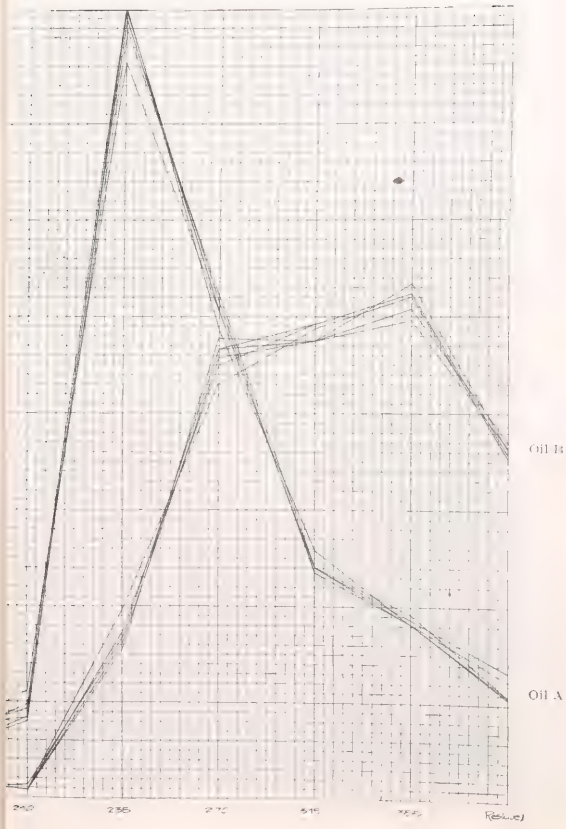


WOOD PRESERVATION.

RAILROAD NO. 6.

OPERATOR R.

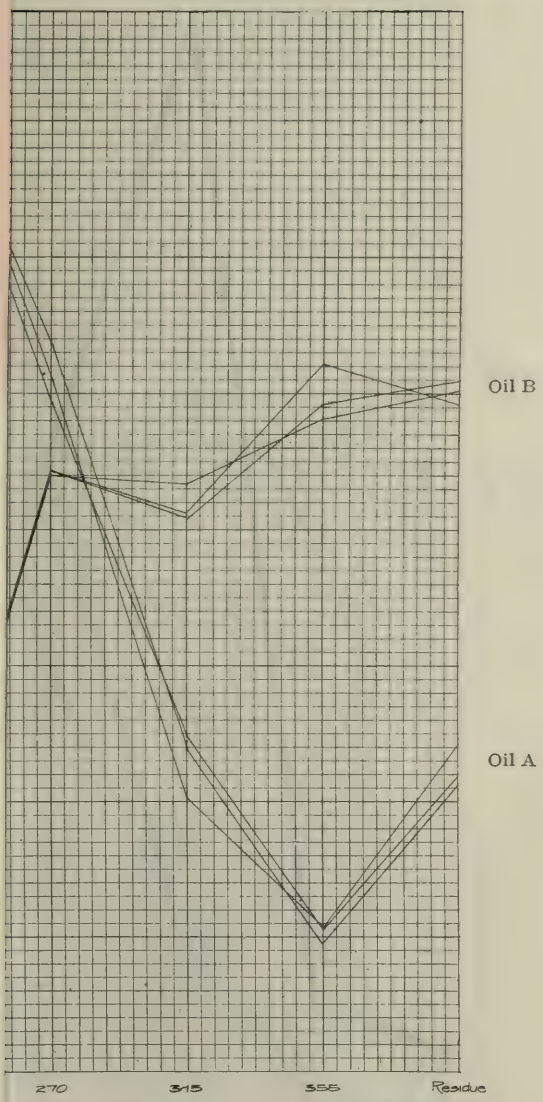
FLASK DISTILLATIONS.

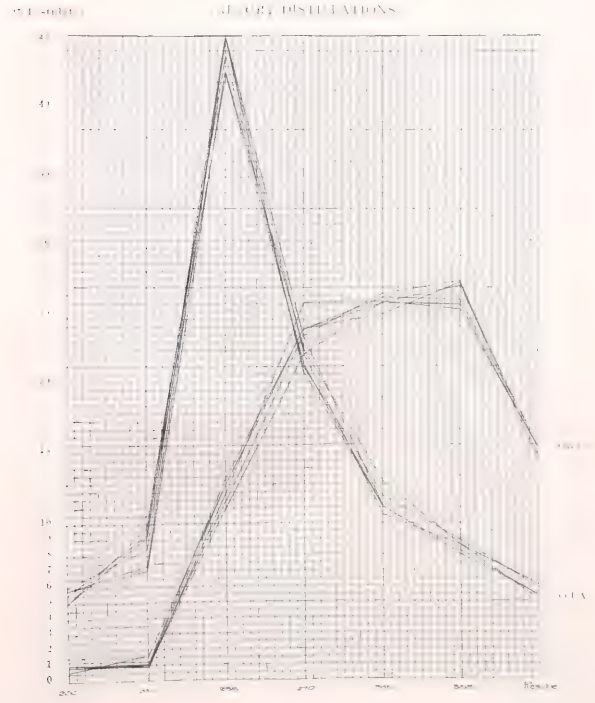


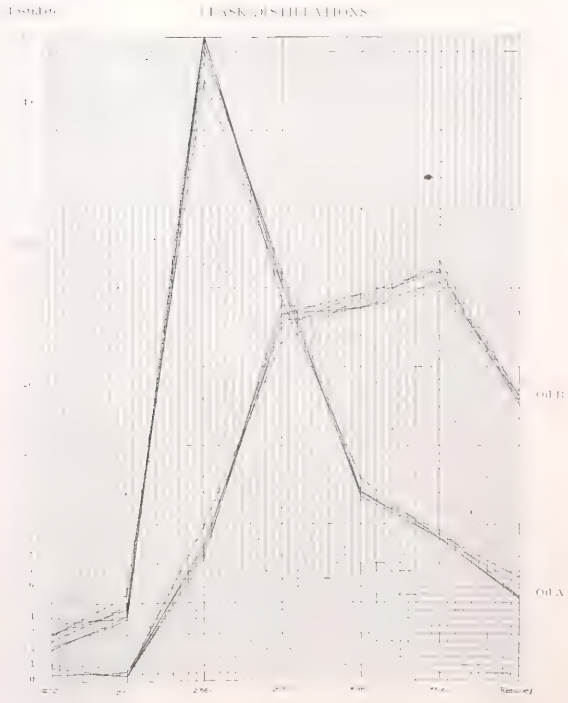
RESERVATION.

LROAD NO. 7.

DISTILLATIONS.




Od B
Od A

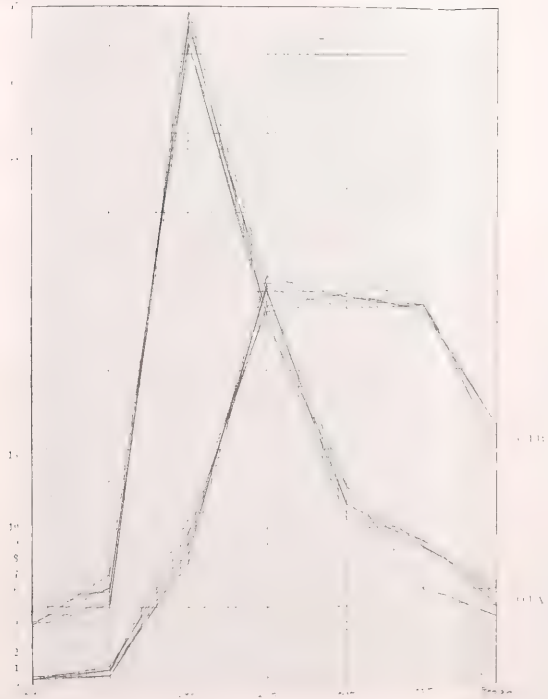

Od B
Od A

WOOD PRESERVATION

CREOSOTE No. 6

OPERATOR B

PILOT DISTILLATIONS

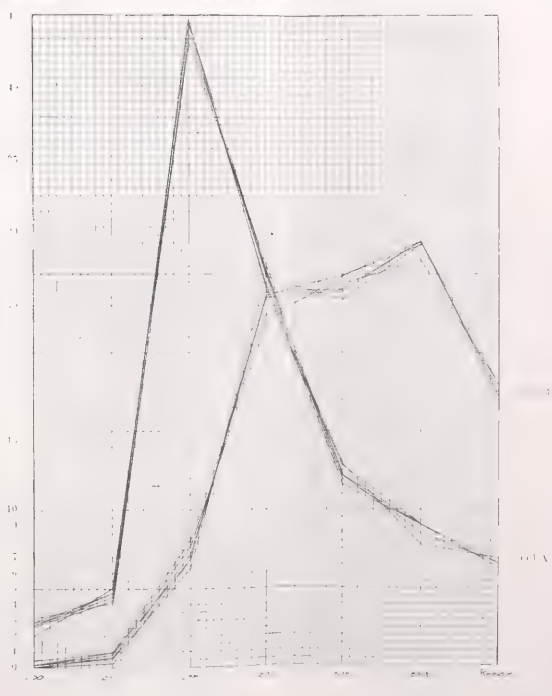


WOOD PRESERVATION

CREOSOTE No. 6

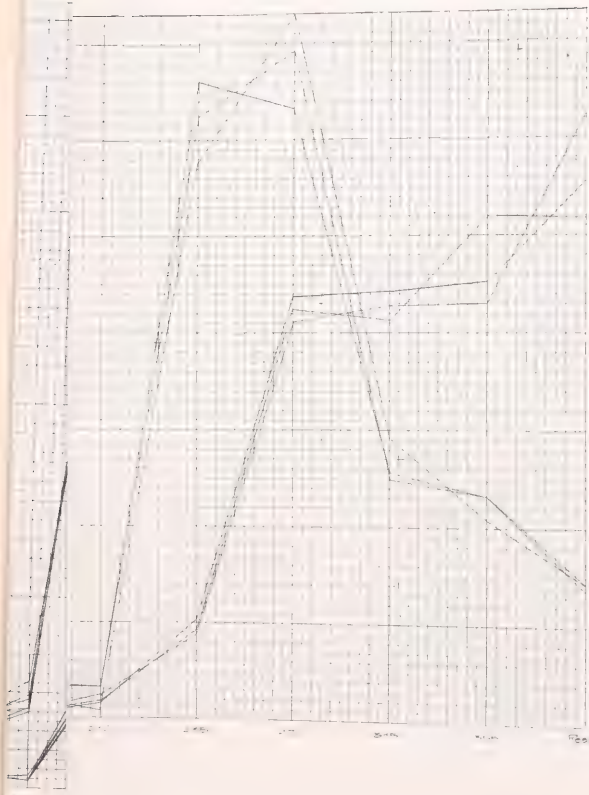
OPERATOR B

FLASK DISTILLATIONS



RAILROAD No. 7.

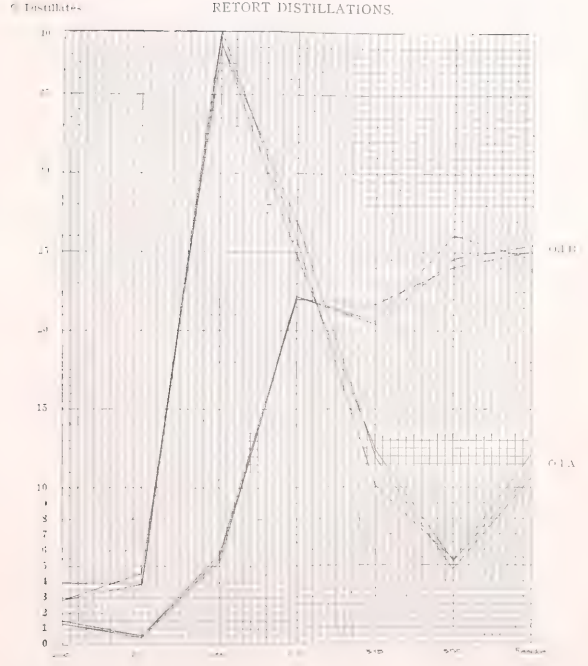
FLASK DISTILLATIONS.



AILWAY ENGINEERING ASSOCIATION
ON WOOD PRESERVATION REPORT
1913 - APPENDIX - "B"
D OF TIE SERVICE TESTS

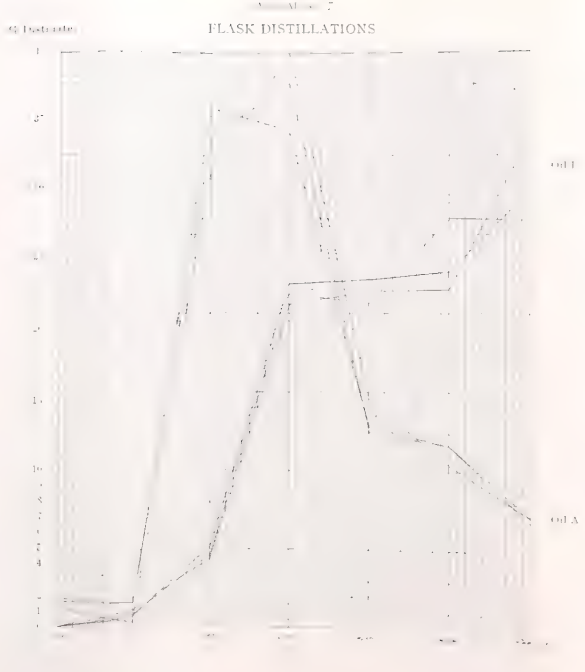
ial	Kind of Treatment	Seasoning			Treating								Absorption per Cu. Ft.			Abso
		Air	Steam		Initial Vacuum		Pressure		Temperature		Final Vacuum		Zinc Cl.	Creosote	Miscel.	Zinc Cl
			Lbs	Time	Inches	Time	Lbs	Time	In Tank	In Retort	Inches	Time				
	Burnettized															
	"															
	Boiled in Zinc Cloride															
	"															
	"															
	"															
	"															
	"															
	"															
	Bakersfield Oil															
	"															
	"															
	"															
	"															
	Boiled in Zinc Cloride Cal. Oil Forced in.															
	Burnett Cal. Oil															
	"															
Both	Zinc Creosote				23	1hr 5min	175	6hrs 10min	153°	152°			0.5#	20#		5.5
"	Straight "													0.675 Gal		
"	Zinc "				23	1hr 0min	175	4hr 50min	137°	157°			0.5#	20#		5.5
"	Straight "				24	0hr 25"			165°	175°				0.675 Gal		
"	Timber Asphalt						Open Tank	20 hrs	110°-208°	10 hours					3.5#-6.11.0.5	
"	Untreated															
Both	Wellhouse	1 Year			26	1 hour	120	3 to 5 hrs	200°	200°-185°	20	30 min.	13.3			
"	"	"	"	"	"	"	"	"	"	"	"	"	14.1			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.2			
"	"	"	"	"	"	"	"	"	"	"	"	"	11.6			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.7			
"	"	"	"	"	"	"	"	"	"	"	"	"	9.4			
"	"	"	"	"	"	"	"	"	"	"	"	"	8.5			
"	"	"	"	"	"	"	"	"	"	"	"	"	9.6			
"	"	"	"	"	"	"	"	"	"	"	"	"	18.2			
"	"	"	"	"	"	"	"	"	"	"	"	"	15.0			
"	"	"	"	"	"	"	"	"	"	"	"	"	14.8			
"	"	"	"	"	"	"	"	"	"	"	"	"	12.9			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.7			
"	Burnettized	"	"	"	"	"	"	"	"	"	"	"	12.7			
"	Wellhouse	"	"	"	"	"	"	"	"	"	"	"	11.0			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.2			
"	"	"	"	"	"	"	"	"	"	"	"	"	11.7			
"	"	"	"	"	"	"	"	"	"	"	"	"	14.1			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.7			
"	"	"	"	"	"	"	"	"	"	"	"	"	12.8			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.7			
"	"	"	"	"	"	"	"	"	"	"	"	"	11.3			
"	"	"	"	"	"	"	"	"	"	"	"	"	8.8			
"	"	"	"	"	"	"	"	"	"	"	"	"	11.2			
"	"	"	"	"	"	"	"	"	"	"	"	"	18.2			
"	"	"	"	"	"	"	"	"	"	"	"	"	14.6			
"	"	"	"	"	"	"	"	"	"	"	"	"	12.8			
"	"	"	"	"	"	"	"	"	"	"	"	"	11.9			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.7			
"	Burnettized	"	"	"	"	"	"	"	"	"	"	"	12.7			
"	Wellhouse	"	"	"	"	"	"	"	"	"	"	"	10.9			
"	"	"	"	"	"	"	"	"	"	"	"	"	12.9			
"	"	"	"	"	"	"	"	"	"	"	"	"	13.9			
"	"	"	"	"	"	"	"	"	"	"	"	"	11.3			
"	"	"	"	"	"	"	"	"	"	"	"	"	11.2			
"	"	"	"	"	"	"	"	"	"	"	"	"	9.7			
"	"	"	"	"	"	"	"	"	"	"	"	"	9.4			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.7			
"	"	"	"	"	"	"	"	"	"	"	"	"	9.7			
"	"	"	"	"	"	"	"	"	"	"	"	"	14.1			
"	"	"	"	"	"	"	"	"	"	"	"	"	12.1			
"	"	"	"	"	"	"	"	"	"	"	"	"	13.6			
"	"	"	"	"	"	"	"	"	"	"	"	"	12.5			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.2			
"	Burnettized	"	"	"	"	"	"	"	"	"	"	"	12.7			
"	Wellhouse	"	"	"	"	"	"	"	"	"	"	"	10.9			
"	"	"	"	"	"	"	"	"	"	"	"	"	8.9			
"	"	"	"	"	"	"	"	"	"	"	"	"	8.9			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.9			
"	Burnettized	"	"	"	"	"	"	"	"	"	"	"	7.4			
"	Creosoted	"	"	"	"	"	"	"	"	"	"	"				
"	Wellhouse	"	"	"	"	"	"	"	"	"	"	"	10.6			
"	"	"	"	"	"	"	"	"	"	"	"	"	10.1			
"	"	"	"	"	"	"	"	"	"	"	"	"	9.4			
"	Burnettized	"	"	"	"	"	"	"	"	"	"	"	7.7			
"	Creosoted	"	"	"	"	"	"	"	"	"	"	"				
"	Untreated	"	"	"	"	"	"	"	"	"	"	"				
"	"

PLATE No. 7



WOOD PRESERVATION

PLATE No. 7



AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION REPORT
1913 - APPENDIX - 'B'
RECORD OF TIE SERVICE TESTS

Company or Organization	Official Reporting	Line No.	Locality of Test	Date Placed	Date Reported	Time of Test	Distance of Test	Number of Ties	Description of Conditions: Sub Grade	Kind of Ballast	Drainage	Weather	Tie Plate	Ties Cut or Screened	Aline ment	Traffic Tons per Annum	Description of Material: Kind of Wood	Size	Sawed or Hewn	Kind of Treatment	Seasoning: Air	Steam: Lbs.	Time	Treating: Initial Vacuum: Pressure	Time	Temperature	Time	Final Vacuum: Inches	Time	Absorption per Cu.Ft.	Absorption per Tie	Inspection: How Often	Made	Charge	Number Removed: Acct.	Mech.	Other Causes	Total	Results: Percent of Total Removed: All	Acct.	Acct.	Average Life	Remarks
A.T.&S.F.Ry.Co.	Mgr. Treating Plants	1	Beaumont Div. Galveston to Texas	May 02	June 1910	8 Yrs 1 Mo		196									Yellow Pine			Untreated																						A Few Treated Ties Strain Seasoned All Creosoted Ties Air Seasoned
		2						100												Burnett Chlo.																						
		3						0												Tel House - Hot																						
		4						101												Zinc Creosote Burnett																						
		5						100												Burnett Ass. Smale																						
		6						100												Wellhouse - "																						
		7						100												Allardyce - "																						
		8						196												Barsona - "																						
		9		North		10 Yrs 5 Mo		93										Red Oak			Untreated																						
		10						86												Burnett - Chlo																						
		11						20												Ass. Smale																						
		12						20												Wellhouse - "																						
		13						20												Allardyce - "																						
		14						19												Barschall - "																						
		15		May 02		10 Yrs 1 Mo		24										Black Oak			Untreated																						
		16						86												Wellhouse Chlo																						
		17						76												Zinc Creosote Burn																						
		18						54												Burnett Ass. Smale																						
		19						20												Wellhouse - "																						
		20						60												Allardyce - "																						
		21						118												Barsona - "																						
		22						0										Tanoak			Untreated																						
		23		Apr 1908		6 Yrs 2 Mo		70												Zinc Creosote Burn																						
		24						10												Burnett Ass. Smale																						
		25						20												Wellhouse - "																						
		26						10												Allardyce - "																						
		27						10												Barschall - "																						
		28		1903		10 Yrs		20										Spanish Oak			Untreated																						
		29						10												Zinc Creosote Burn																						
		30						21												Burnett Ass. Smale																						
		31						20												Wellhouse - "																						
		32						10												Allardyce - "																						
		33		1897		10 Yrs		120										Willow Oak			Untreated																						
		34						11												Zinc Creosote Burn																						
		35						70												Burnett Ass. Smale																						
		36						0												Wellhouse - "																						
		37						0												Allardyce - "																						
		38						20												Barschall - "																						
		39						100										Beech			Untreated																						
		40		Feb 02		11 Yrs 2 Mo		30												Zinc Creosote Burn																						
		41						93												Burnett Ass. Chlo																						
		42						100												Wellhouse - "																						
		43						50												Allardyce - " Smale																						
		44						98												Barschall - "																						
		45		Apr 02		10 Yrs 2 Mo		107										Hemlock			Untreated																						
		46						49												Zinc Creosote Burn																						
		47						150												Burnett Chlo																						
		48						50												Wellhouse - Chlo																						
		49						50												Allardyce Ass. Smale																						
		50						100												Barschall - "																						
		51		May 02		10 Yrs 1 Mo		49										Tamarack			Untreated																						
		52						61												Zinc Creosote Burn																						
		53						49												Burnett Chlo																						
		54						50												Wellhouse - "																						
		55						50												Allardyce Ass. Smale																						
		56						196												Barschall - "																						
		57						100										Short Leaf Pine			Untreated																						
		58						20												Zinc Creosote Burn																						
		59						1000												Burnett Ass. Smale																						
		60						50												Wellhouse - "																						
		61						50												Allardyce - "																						
		62						99												Barschall - "																						
		63						100										Redheart Long Pine			Untreated																						
		64		Apr 02		10 Yrs 2 Mo		93												Zinc Creosote Burn																						
		65						50												Burnett Ass. Chlo																						
		66						100												Wellhouse - "																						
		67						100												Barschall - "																						
		68						20												Allardyce - "																						
		69						100												Beaumont Chlo																						
		70						100												Burnett Chlo																						
		71						100												Spar Pine Ass.																						
		72						100										Loblolly			Untreated																						
		73						19												Zinc Creosote Beat																						
		74						99												Burnett Ass. Smale																						
		75						99												Wellhouse - "																						
		76						45												Allardyce - "																						
		77						99												Barschall - "																						
		78						12												Beaumont Chlo																						
		79						80												Burnett Chlo																						
		80						100												Spar Pine Ass.																						
		81						54										Pines			Unbarked																						
		82		Apr 02		7 Yrs 2 Mo		19												Burnett Chlo																						
		83		Feb 02		10 Yrs 4 Mo		74												Burnett Chlo																						
		84						8												Barschall																						
		85						5										Cabbage Palm			Burnetted																						
		86						5												Burnett Cr. Creosote																						
		87						4										Long Pine			Burnetted																						
		88						3										Short Pine			"																						
		89						10										New Mex. Red Pine			"																						
		90						1										Figure			"																						

Yearly Over Twenty Per Cent.

tion per Tie		Inspection		Number Removed				Results				Remarks
		How Often Made	Official in Charge	Acct Decay	Mech Wear	Other Causes	Total	Percent of Total Removed All Causes	Acct Decay	Acct Mech Wear	Average Life	
Creosote	Miscel											
							2	100			About 6 years	
							0	0				
							1	13				
							1	25				
							0	0				
							1	100			About 2 years	
							1	100			About 2 years	
							3	100			About 2 years	
							3	100			About 2 years	
							1	100			About 2 years	
							1	25				Removed in 1908 for Inspection Permit Condition.
							0	0				
							1	50				
							2	67				
							0	0				
							2	100			About 2 years	
							0	0				
							0	0				
ions		Annually	Engr	0	0	0	0	0	0	0		
5Gal		or at	Mof W	0	0	0	0	0	0	0		
ions		designat	"	0	0	0	0	0	0	0		
5Gal		Periods	"	0	0	0	0	0	0	0		
	1Gal/ft 2.25Gal	"	"	0	0	0	0	0	0	0		
		Annually	Asst Genl Mgr									
		"	"									
		"	"									
		"	"

ICAN RAILWAY ENGINEERING ASSOCIATION
TTEE ON WOOD PRESERVATION REPORT
1913 - APPENDIX - "B"
RECORD OF TIE SERVICE TESTS

Organization	Description of Material				Kind of Treatment	Seasoning			Treating						Absorption	
	Wood	Size	Class	Sawed or Hewn		Air	Steam Lbs	Steam Time	Initial Vacuum Inches	Initial Vacuum Time	Pressure Lbs	Pressure Time	Temperature In Tank	Temperature In Retort	Final Vacuum Inches	Final Vacuum Time	Zinc Cl.	Creosote
Galveston	Pine	7-9-8½	First	Hewn	Creosote	Unknown	None										17.4	
	"	"	"	"	"	"	"										"	
	Oak	"	"	"	"	"	"										"	
	"	"	"	"	"	"	"										"	
	Oak	6"8"-8	First	Hewn	Rueping Process	2 years	None		Air	Pressure	180	2hr 10 Min	175		23½	1hr 40 Min	453 lbs	
	Elm	"	"	Sawed	using Creosote Oil	"	"		80	30 Min	"	2hr	175		24	1hr 30 Min	366 lbs	
	Oak 8	"	"	Both	Gussanni	Varied					127 to 133	15 to 60 mm						
	Elm	"	"	"	Creosote	"					175	1 or 2 hrs			18 to 24			
		"	"	"	Rueping with Creosote	"					100 to 250	2 or 3 hrs						
		"	"	"	Immersed in Oil	"					125	1hr						
		"	"	"	Bethell	"												
		"	"	"	Creosote	"												
		7-9-8		Sawed	Burnettized	Air			24	30 Min			165°				0.25%	

Georg
Lake
Michic

Mexicar

N.Y. N

Norfolk

Penn. L
Northw

Oregon
Railroad
(Union

AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION REPORT
1913 - APPENDIX - "B"
RECORD OF TIE SERVICE TESTS

| Company or Organization | Official Reporting | Test No | Locality of Test | Date Placed | Date Reported | Time of Test | Distance of Test | Number of Ties | Description of Conditions: Sub Grade | Kind of Soil | Ballast | Drainage | W't and Section of Rail | Tie Plate: Size | Ties Cut or Kind of per Mule Screw Bottom of Track | Spike | Alinement | Traffic Tons per Annum | Description of Material: Kind of Wood | Size | Class or Sawed Hewn | Kind of Treatment | Seasoning: Air | Steam Lbs | Time | Treating: Initial Vacuum Inches | Time | Pressure Lbs | Time | Temperature In Tank | Retort | Final Vacuum Inches | Time | Absorption per Cu Ft: Zinc Cl | Creosote | Miscel | Absorption per Tie: Zinc Cl | Creosote | Miscel | Inspection: How Often | Official in Charge | Number Removed: Acct Decay | Mech Wear | Other Causes | Total | Results: Percent of Total Removed: All Causes | Acct Decay | Acct Mech Wear | Average Life | Remarks |
|---|---|---

AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION REPORT
913 - APPENDIX - "B"
RECORD OF TIE SERVICE TESTS

Company or Organization	Officials Reporting	No.	Locality of Test	Date Placed	Time in Track	Distance Tangent	Description of Construction: Drainage	Tie Plates	Rail Section	Rail Fastenings	Species of Timber	Kind of Treatment	Seasoning: Air	Seasoning: Steaming	Treating: Initial	Treating: Temperature	Treating: Final	Absorption per Tie: Gross	Absorption per Tie: Net	Inspection: How Often	Inspection: Made Under	Number Removed: Accl.	Number Removed: Mech.	Number Removed: Other Causes	Number Removed: Total	Results: Percent Life Removed All	Results: Percent Life Removed Accl.	Results: Average Life	Remarks
Delaware, Lackawanna & Western	Engineer M. of W.		Hackensack, Secaucus & Kearny, N.J.																										
		1																											
		2																											
		3																											
		4																											
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Cu Ft Misce	Absorption per Te Zinc	Creosote	Misce	Inspection How Often	Inspection Made	Change	Number Removed Act, Mech	Other Decay	Wear	Other	Total	Results Percent of Total Removed Ag Causes	Acct Decay	Acct Mech Wear	Acct	Average Life	Remarks

REPORT OF COMMITTEE III—ON TIES.

L. A. Downs, *Chairman;*
H. W. Brown,
W. J. Burton,
L. C. Hartley,
E. D. Jackson,
H. C. Landon,
F. R. Layng,
E. R. Lewis,
R. J. Parker,
G. W. Merrell, *Vice-Chairman;*
L. M. Perkins,
J. G. Shillinger,
G. D. Swingly,
D. W. Thrower,
H. S. Wilgus,
Louis Yager,
E. C. Young,
Committee.

To the Members of the American Railway Engineering Association:

The Board of Direction assigned the following subjects to the Committee on Ties:

(1) Report on the effect of design of tie-plates and track spikes on durability of ties.

(2) Continue study of the stresses to which cross-ties are subjected, and determine size required.

(3) Report on economy in labor and material effected through use of treated ties compared with untreated ties.

(4) Continue the compilation of information as to the use of metal, composite and concrete ties.

The report on the effect of design of tie-plates and track spikes on durability of ties is given in Appendix A, and is submitted as information.

The report on the subject of stresses to which cross-ties are subjected is given in Appendix B.

Your Committee also reports progress on the subject of economy in labor and material effected through use of treated ties compared with untreated ties.

In Appendix C is given a compilation as to the use of metal, composite and concrete ties.

AMERICAN RAILWAY ENGINEERING ASSOCIATION
COMMITTEE ON WOOD PRESERVATION REPORT
1913 · APPENDIX "B"
RECORD OF TIE SERVICE TESTS

Company or Organization	Official Reporting	No. Lines	Locality of Test	Date Placed	Date Reported	Time of Test	Distance of Test	Number of Ties	Description of Location: Sub-Grade	Kind of Ballast	Drainage	Width of Section	Tie Plate: Size	Kind of Bottom	Ties: Cut or Adzed	Kind of Track Spike	Alinement	Traffic: Tons per Annum	Character of Material: Kind	Size	Class	Screened	Kind of Wood	Kind of Treatment	Seasoning: Air	Steaming: Lbs.	Steaming: Time	Treating: Pressure	Treating: Temperature	Treating: Time	Final Vacuum: Inches	Final Vacuum: Time	Absorption per Tie: Zinc Cl	Absorption per Tie: Creosote	Absorption per Tie: Miscellaneous	Inspection: How Often	Inspection: Made by	Charge	Number Removed: Account of Decay	Number Removed: Account of Wear	Number Removed: Account of Other Defects	Results: Percent of Total Removed	Results: Average Life	Remarks
Queen & Crescent Route	Chief Engineer	1	Birmingham Ala	June '01	Aug '02	1 yr 2 mo	33	50	Clay	Slag	Good	8'6"	None		Cut				Fine				Burnett									17.4											
Alabama	"	2	"	"	"	"	"	50	"	"	"	"	"		"				Hard				"									"											
Great Southern R	"	3	"	"	"	"	"	50	"	"	"	"	"		"				Water oak				"									"											
"	"	4	"	"	"	"	"	50	"	"	"	"	"		"				Elm				"									"											
St Louis & San Francisco R.	Chief Engineer	1	St Clair Mc	Oct '96	Sept '97	1 yr 11 mo	130.0	752	Sandy Gravel Loam	Gravel	Good	7'6"	None		Cut			890000	Ry	7'0"	6'8"	8	Flat	Red oak	Dipping Open tank	Open	None	Air pressure 80 lbs.	30 Min	Open tank 2 hr.	75	2 1/2 hr.	42	353 lbs	Zinc Chloride		Annually	Foreman		0	0		C			See Remarks
"	"	2	"	"	"	"	"	32	"	"	"	"	"		"				Ry				Sand	Burnett	Pressure tank			80 lbs	2 hr	75	2d	30	366 lbs	"											
"	"	3	Pacific Mc	Oct '05	Apr '12	6 yr 6 mo		43	"	"	"	"	"		"	Tangent	Main		Ry	7'0"	6'8"	8	Butt	Red oak	Open tank	Open		Varying		70 to 80 lbs											3	?		See Remarks
"	"	4	"	"	"	"	"	73	"	"	"	"	"		"				Swamp				Gum		Timing tank				40 lbs		6 hr									5	E		
"	"	5	"	"	"	"	"	40	"	"	"	"	"		"				Ry	7'0"	6'8"	8	Butt	Red oak or magnolia	Pressure tank				25 lbs		2 hr										C		
"	"	6	"	"	"	"	"		"	"	"	"	"		"				"	"	"	"	"		immersed in Oil																C		
"	"	7	"	"	"	"	76		"	"	"	"	"		"				"	"	"	"	"		Butts															2	26		Preservative treating
"	"	8	"	"	"	"	24		"	"	"	"	"		"				"	"	"	"	"		Creosote															2	8.3		Less than 5 years
Southern Pacific Ry	Asst Chief Engr	1	Various	1905 & 1912		368 Miles		766.79	Various	Stone & Gravel	Good	7'6" & 9'0"	None				Medium		Fir		7'9"	8"	Flat	Sound	Burnettized	Air		24	30 min		65°			C 25#			Annually	Inspector							4	

Appendix A.

REPORT ON THE DESIGN OF TIE-PLATES AND SPIKES ON THE DURABILITY OF TIES.

A circular letter requesting information relative to this subject was sent to members of the Association. The following is a list of the questions asked:

(1) Do you use flat, longitudinal flange, transverse flange, pronged or corrugated tie-plates?

(2) Please send plan of your standard tie-plate, and give method of applying.

(3) Do you use screw or cut spikes?

(4) In your opinion, how far should tie-plate extend outside base of rail to overcome side thrust, and what should be total bearing area? Give reasons for your conclusions.

Replies were received from 61 railroads. These have been tabulated in statement form, and herewith submitted to the Association, as information. The number of roads using only one design of tie-plate and kind of plate used, are:

Longitudinal flange	16
Transverse flange	8
Flat	5
Pronged	4
Corrugated	11

The number of roads using two designs of tie-plates and kind of plates used, are:

Longitudinal flange and flat	3
Longitudinal flange and pronged	1
Longitudinal flange and corrugated	1
Transverse flange and pronged	1
Transverse flange and corrugated	1
Flat and pronged	1
Flat and corrugated	1
Pronged and corrugated	1

The number of roads using three designs of tie-plates and kind of plates used, are:

Longitudinal flange, transverse and flat	1
Longitudinal flange, transverse and corrugated	2
Longitudinal flange, flat and corrugated	1
Longitudinal flange, pronged and corrugated	1
Transverse flange, flat and pronged	1

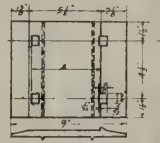
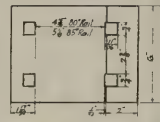
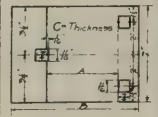
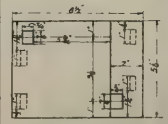
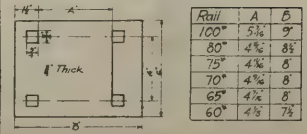
The number of roads using four designs of tie-plates and kind of plates used, are:

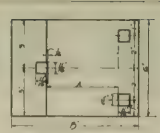
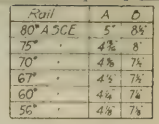
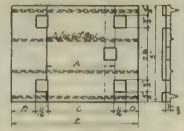
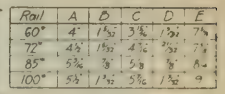
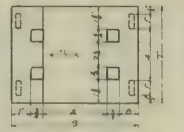
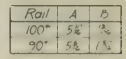
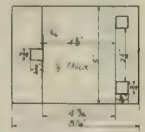
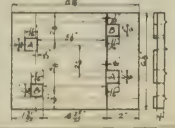
Longitudinal flange, transverse, pronged and corrugated	1

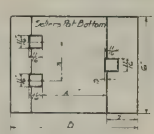
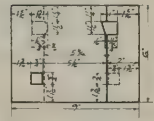
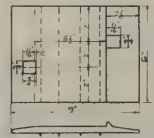
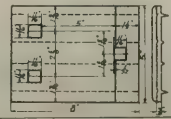
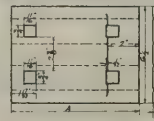
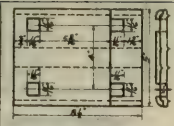
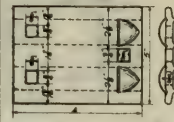
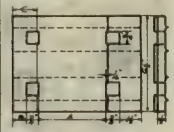
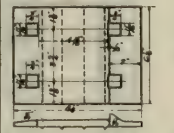
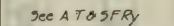
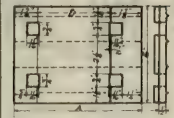
CONCLUSION.

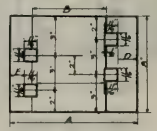
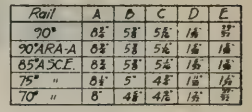
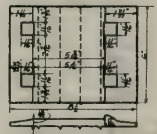
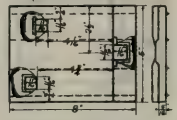
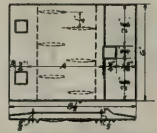
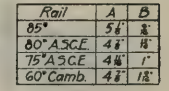
The Committee was unable to obtain any definite information bearing on the relative effect of the different designs of tie-plates and spikes on the life of ties, but it is thought that experiments, which are now being conducted, will throw some light on this subject in the near future.

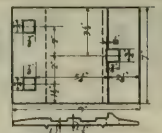
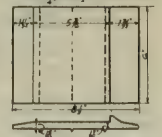
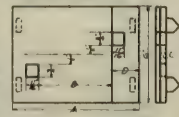
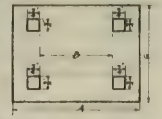
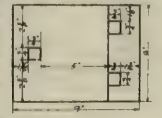
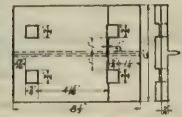
PRACTICE OF VARIOUS RAILWAYS AS TO TIE-PLATES.

Name of Railroad.	Do you use flat, longitudinal flange, transverse flange, pronged or corrugated tie-plates?	Please send plan of your standard tie-plate and give method of applying.	Do you use screw or cut spikes?	In your opinion, how far should tie-plate extend outside base of rail to overcome side thrust, and what should be total bearing area? Give reasons for your conclusions.	Kind of Plate Used.
A., T. & S. F.....	Pronged or corrugated flange.	Raise rail and place plate under rail.	Cut; experimenting with screw spike.	Shoulder side, 2 5-32 in. Other side, 2 1-16 in.	
Algamo Central & Hudson Bay.....	Corrugated.	All used to date applied on new work as track is laid.	Cut spike.	2-in. extension is ample. Width limited by ties used. Total area 51 sq. in. Not economical to use larger plates.	
Balto. & Ohio.....	Transverse and longitudinal flange and corrugated.	Ties first adzed, rail raised and plate placed. Then spike and plates seated by maul and traffic.	Cut; experimenting with screw spike.	At least 2 in.	
Bangor & Aroostook.....	Goldie claw tie-plate.	Driven into tie with hammer.	Cut.	Shoulder side, 2 in. Other side, 1 3-16 in. Total area depends on kind of ties.	
Boston & Albany..	Longitudinal flange	Tie is adzed, rail raised and plate is put in seat with maul.	Cut.	Average 2 in. for both sides. Otherwise, fiber will crush under plate.	

B. & O. C. T.....	Longitudinal flange and pronged or corrugated.	When tie is renewed plate is put under until tie settles. Spikes are drawn and rail raised enough to permit plate.	Cut.	Not under 2 in., and plate should be thick enough not to break.	 
Boston & Maine...	Longitudinal flanged.	Put on by machine or also pushed under by train.	Cut.	Should extend on both sides at least 2¼ in. It has been experienced that a plate of less width sinks into ties.	 
Buffalo, Rochester & Pittsburgh.....	Goldie claw plates.	Plates are put on ties before they are put in track. When plates are put on tie, rail is thrown out. Ties are adzed.	Cut.	Consider 1⅝ in. sufficient. Total bearing area 63 sq. in.	 
Chicago Junction..	Flat plates.	The bottom of plates being flat, they are very easily slipped under rail.	Cut.	Both sides should have 2 in.	
C., C., C. & St. L.	Longitudinal.	Applied on curve over 1 deg. and at other places where traffic requires it.	Cut.	Should not be less than 1½ in., depending on size of plate. Total bearing area should be great enough to have safe loading.	80"A.S.C.E. Rail
Chicago Great Western	Longitudinal flanged.		Cut.	Area should be sufficient to prevent crushing, depending on kind of ties used.	 For 85"Rail - Holes A-A Only For 75"Rail - Interchangeable Holes A-A & B-B

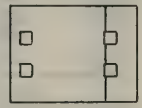
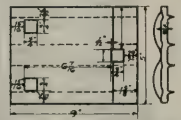
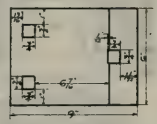
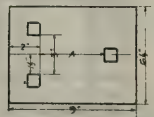
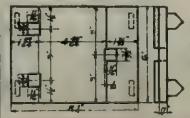
Name of Railroad.	Do you use flat, longitudinal flange, transverse flange, pronged or corrugated tie-plates?	Please send plan of your standard tie-plate and give method of applying.	Do you use screw or cut spikes?	In your opinion, how far should tie-plate extend outside base of rail to overcome side thrust, and what should be total bearing area? Give reasons for your conclusions.	Kind of Plate Used.
Chicago & Alton—Toledo, St. Louis & Western.....	Corrugated tie-plate. Sellers type often used.		Cut.	Shoulder side, 2 in. Other side, 2 1-16—2½ in., depending on weight of rail.	
C. & N. W.....	Corrugated type.		Cut.	Shoulder side, 2 in. Other side, 1 55-64 in.	 For 100# A.R.A-A Rail —Left ----Right Sellers Patent Bottom
C., B. & Q.....	Sellers corrugated type and flange longitudinal.		Cut.	Width of base depends on section of rail, thickness of plate, weight of rolling stock and kind of ties used.	 For 100# A.R.A Rail Transverse Flanges and Sellers Patent Bottom
Canadian Pacific...	Sellers type used, but this has been making more or less noise, and a corrugated type with shoulder has been adopted.	The tie-plates are placed, and rolling equipment seats it in ties.	Cut.	Bearing area should be great enough to prevent crushing on ties, depending on kind of ties.	Sellers Patent also used
Duluth, Missabe & Northern	Longitudinal flange and Wolhaupter shoulder flange.	Rail raised and plate placed under, allowing weight of train to drive flanges into wood, then spikes are driven.	Cut.	The bearing area depends on kind of ties used, oak requiring less than pine.	 For 80# A.S.C.E. Rail

Denver & Rio Grande	All types of flat and flanged tie-plates.		Cut.	Bearing area depends on wheel loads and kind of ties.	
Elgin, Joliet & Eastern	Wolhaupter.		Cut.	1½ in. sufficient on both sides.	
Frisco Lines.....	Longitudinal flanged.	The plates are put under and weight of rail will sink flanges into ties.	Cut; experimenting on screw, but to no additional advantages.	Shoulder side, 2¼ in. Other side, 1½ in. to 1 15-32 in. It is the opinion that these plates should be larger if softer ties were used.	
Great Northern....	Transverse flange.		Cut.	Plate designed with 53 per cent. outside center line. Total bearing area should be 60 sq. in. for main tracks, not less than 40 sq. in. branch lines.	
Gulf, Colorado & Santa Fe.....	Transverse flange, two ribs ¼ in. in depth.		Cut.	Made no investigation.	
Grand Trunk System	Longitudinal flanged, four ribs.		Cut.	At least one-third of plate should be outside of rail bearing. Total area varying with ties used. At least 15 per cent. greater for softwood or creosoted ties and 10 per cent. on hardwood ties. Less mechanical wear.	

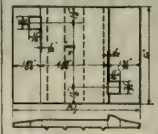
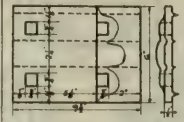
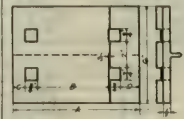
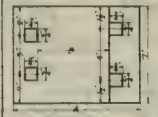
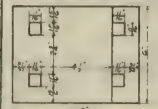
Name of Railroad.	Do you use flat, longitudinal flange, transverse flange, pronged or corrugated tie-plates?	Please send plan of your standard tie-plate and give method of applying.	Do you use screw or cut spikes?	In your opinion, how far should tie-plate extend outside base of rail to overcome side thrust, and what should be total bearing area? Give reasons for your conclusions.	Kind of Plate Used.
Illinois Central.....	Flat tie-plates.	Used with cut spikes on curves.	Cut.	Plate should project outside of rail from 1¾ in. to 2 in. Bearing area depends on size of rail, load to be carried and kind of tie.	 
Indiana Harbor Belt	Transverse flanged.		Cut.	Extension of 1 31-32 in. on outside and 1 11-32 in. inside have given good results. Total area 51 sq. in.	 For 85° Rail
International & Great Northern..	Longitudinal flange.		Cut.	Both sides of plate should be 1¾ in.	 75° Sect-A Rail 56° Sect-A Rail
Kansas City Southern	Corrugated.	Apply on every tie on curves over 3 deg.	Cut.	Should extend 2½ in. to overcome side thrust. Total area, 51 sq. in. This will give a safe bearing.	 
Kanawha & Michigan	Longitudinal flanged. Goldie claw plate for 90-lb. A. S. C. E. rail, account mechanical wear.		Cut.	Should extend 2½ in. on both sides, and thick enough not to break or deflect.	90° A.S.C.E. Rail Goldie Plate

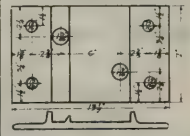
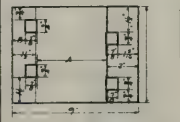
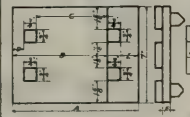
Lehigh Valley.....	Transverse flange.	Place under rail and spike.	Cut.	Should be as wide as practicable and no longer than to provide for proper spike holes.	 100# A.R.A.A Rail
Lake Superior & Ishpeming	Transverse flange. Sellers patent tie-plate.		Cut.	For oak or hemlock, not less than 2 in. Total area, 51 sq. in. For cedar not less than 2½ in. Total area, 54 sq. in.	 Transverse Flanges and Sellers Patent Bottom.
L. & N.....	Goldie claw tie-plate.	Applied with cut spikes.	Cut.	No study of this has been made, but plate should be ½ in. thick and ¼ in. less projection on gage side than on outside.	
Long Island.....	Longitudinal flange.		Screw and cut.	1½-in. projection for 80-lb. rail; 1¾-in. projection for 100-lb. rail.	
Lehigh & New England	Longitudinal flange.	Applied with cut spikes, but no special method of applying.	Cut.	2 1-16-in. projection on shoulder side; 1 15-16-in. projection other side.	 80# Rail
Lake Erie & Western	Longitudinal flange.	Rail raised and plate put under. Train is allowed to seat plate.	Cut.	2-in. projection is sufficient for hard woods.	 80# A.S.C.E. Rail

Rail	A	B	C	D
90#	8"	4⅛"	1"	1⅛"
80#	7¼"	4⅛"	⅞"	1⅛"
70#	7"	4⅛"	⅞"	1⅛"
56½#	7"	3⅛"	⅞"	1⅛"

Rail	A	D
100#	9"	5⅛"
80#	8"	5"

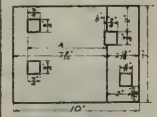
Name of Railroad.	Do you use flat, longitudinal flange, transverse flange, pronged or corrugated tie-plates?	Please send plan of your standard tie-plate and give method of applying.	Do you use screw or cut spikes?	In your opinion, how far should tie-plate extend outside base of rail to overcome side thrust, and what should be total bearing area? Give reasons for your conclusions.	Kind of Plate Used.
Missouri Pacific...	Flat bottom and corrugated used.	Applied with cut spikes.	Cut.	Specifications of M. P. R. R. require 2-in. projection. Total area depends on ties and rail used.	 Flat or Corrugated Bottom Drawn from specifications
Michigan Central...	Transverse flange.		Cut and some screw.	Have experienced that 1½—1¾-in. projection on shoulder side and 1 9-16—2 13-16-in. depending on weight of rail. Plate to be thick enough not to break or buckle.	 100# Rail Walhaupter Tie Plate  100# Rail Sellers Patent
Mobile & Ohio.....	Corrugated.	Ties are adzed and plates applied with cut spikes.	Cut.	2 3-16 in. shoulder side; 2 in. other side.	 The distance A varies with size of rail Sellers Patent used
Northern Pacific...	Longitudinal and for curves greater than 3 deg. use pronged.		Cut.	Should extend 2 in. and have total bearing area of 51 in. This result obtained from many years' tests.	 90# Rail For curves sharper than 3°

Northern Pacific...					 90# Rail For tangents and curves of 3° or less
Norfolk & Western	Longitudinal flange.	Put under rail and driven down with sledge.	Cut.	Should extend 2¾ in. Experienced that 2¼ in. was too small. Outer edge of plate was driven into tie and rail tilted. Total bearing area 57 sq. in.	 100# A.R.A.-B Rail Wolhaupter Plate
New York Central Lines	Single longitudinal flange.	First seat rail on ties, then pull spikes and raise rail a little and drive plate under.	Cut.	2 in. on shoulder side; 1 9-16 in. on other side. These projections give us satisfaction.	
New York Central & Hudson River.	Two longitudinal flanges for creosoted ties. Flat bottom for other ties.	Plates are placed and seated in tie by weight of train.	Cut - screw spikes for tracks in paved street.	Under 100-lb. rail under heavy traffic and high speed, plates should project 5¾ in. on outside and 2¾ in. on inside.	
Northern Electric.	Wolhaupter, transverse flange and corrugated.	Drive into tie with wood mallet until plate is flush with tie.	Cut.	Should extend 2 in., and total bearing area 60 sq. in. These used under 140-lb. girder rail.	See Norfolk & Western.
National of Mexico.	Flat bottom.		Cut.	1 21-32 in. on both sides.	 70# Rail

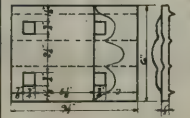
Name of Railroad.	Do you use flat, longitudinal flange, transverse flange, pronged or corrugated tie-plates?	Please send plan of your standard tie-plate and give method of applying.	Do you use screw or cut spikes?	In your opinion, how far should tie-plate extend outside base of rail to overcome side thrust, and what should be total bearing area? Give reasons for your conclusions.	Kind of Plate Used.
Pennsylvania Railroad Lines East.	Transverse flange and "cushion" have been standard, but it is likely a flat-bottom plate will be adopted as standard.	Tie-plates are applied to ties and seated by traffic.	Cut.	The projection depends on the alinement. And total bearing area depends on tonnage. Neither can be fixed to suit all conditions.	 100# Rail Screw Spike
				2⅜ in. for 100-lb. and 2⅛ in. for 85-lb. rail on outside; 1⅝ in. for 100-lb. and 1½ in. for 85-lb. rail on inside. With this extension on outside it is found that plate is imbedded in tie. Are now considering making them longer. Total bearing area is 63 sq in. This is too small and are considering making larger plate.	 

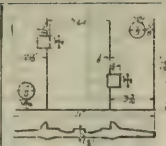
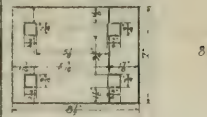
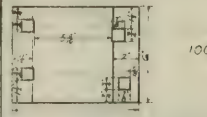
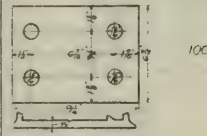
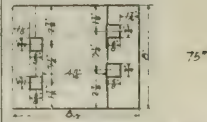
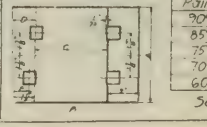
Rail	A	B
100#	5⅛"	4"
80#	4⅝"	1⅛"

Rail	A	B	C	D	E	F
100#P5	9"	6⅝"	4⅝"	1⅝"	1⅜"	⅜"
85#P5	8¼"	6⅛"	4⅜"	1⅛"	1⅜"	⅜"

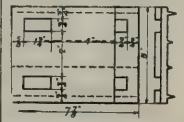
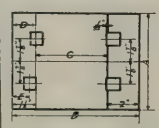
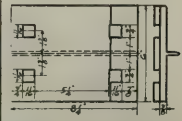
Philadelphia & Reading	Flat bottom.		Cut.	2 13-16 in. shoulder side; 1⅞-2¾ in. other side.	

Rail	A
100#	5⅛
90#B	5⅛
90#A	4⅝
80#	4⅝
70#	4⅝

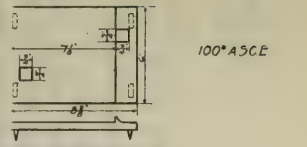
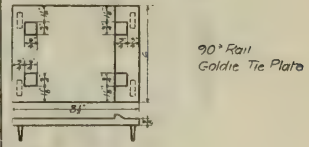
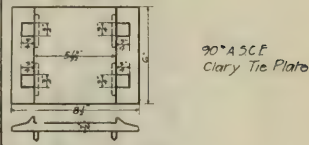
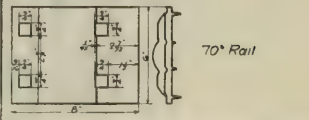
Pittsburgh, Shawmut & Northern.	Longitudinal flanged.	Put plate under rail and allow train to seat them.	Cut.	The projection depends on width of base of rail as compared with height. Weight of rolling stock, density traffic, kind of timber and design of plate.	 100# A.R.A.-B Rail Wolhaupter Plate

Pittsburg & Lake Erie	Flat, double shoulder.	Ties are adzed and plate put on at treating plant with screw spike; cut spikes are used when plates are put on in track.	Screw and cut.	Enough to preserve tie against cutting. Bearing area at least 75 sq. in. It is useless to preserve tie from decay and don't prevent it from wearing out.	
Queen & Crescent Route—C., N. O. & T. P.—A. G. S.	Longitudinal, transverse, pronged and corrugated.	Applied without any special method.	Cut.	Should extend 1⅞ in. outside, and 1 7-16 in. inside.	
R., F. & P.....	Flat, cushion bottom, Wolhaupter corrugated.	Plates are placed when track is surfaced and when new ties are put in.	Cut.	Should extend 2 in. on outside and 1½ in. on inside. Bearing area for oak ties 54 sq. in. for intermediates and 64 sq. in. for joints.	
Rock Island Lines.	Flat-bottom plates for screw spikes; longitudinal flanged for cut spikes.		Screw 100 lb., cut 90 lb. and under.	2¼ in. maximum projection of tie-plate. And bearing should not be over 335 lbs. per sq. in. This has been adopted from tests.	
San Pedro, Los Angeles & Salt Lake	Flat bottom is standard; Hart and Wolhaupter, longitudinal.	Applied as rail is laid.	Cut.	2 in. on outside and 1¾ in. on inside has given satisfactory results. And consider this is sufficient.	
St. Louis Southwestern	Corrugated and Sellers Anchor.	Place plate on tie and seat tie with spike maul.	Cut.	The projection of our tie-plates used seems to be sufficient.	

PRACTICE OF VARIOUS RAILWAYS AS TO TIE-PLATES—Continued.

Name of Railroad.	Do you use flat, longitudinal flange, transverse flange, pronged or corrugated tie-plates?	Please send plan of your standard tie-plate and give method of applying.	Do you use screw or cut spikes?	In your opinion, how far should tie-plate extend outside base of rail to overcome side thrust, and what should be total bearing area? Give reasons for your conclusions.	Kind of Plate Used.
Seaboard Air Line.	Longitudinal flange.	Plates are put under rail and seated by passing trains.	Cut.	Would prefer 6-in. by 8-in. plate for 5-in. rail base, and 9 in. long for 6-in. rail base. Our standards of 5 in. by 7⅞ in. are satisfactory.	 For all weights of rail
Spokane & Inland Empire	Sellers type of corrugated plates.		Cut.	Should have 2-in. extension and should be 1 in. narrower than width of tie.	
Terminal R. R. Assn. of St. Louis.	Corrugated.		Cut.	Extension and total area depends on kind of ties used; 2-in. extension outside and 1⅝-in. inside, give us satisfaction on oak ties. Area 51 sq. in.	80° A.S.C.E.
Toledo & Ohio Central	Single longitudinal flange.		Cut.	Bearing area should be safe for loads and class of ties used.	 90° A.S.C.E.
Temiskaming & Northern Ont. ..	Sellers Anchor bottom.		Cut.	With 80-lb. rail think tie-plate should be 6 in. by 9 in.	Sellers Patent

Rail	A	B	C	D	E	Plate Holes
90°	7"	8½"	5"	1⅝"	1⅝"	⅞" x ⅞"
85°	7"	8½"	5"	1⅝"	1⅝"	⅞"
75°	6"	8½"	5"	1⅜"	1⅜"	1"
70°	6"	8½"	5"	1⅜"	1⅜"	1"
60°	6"	8½"	4⅝"	1⅜"	1⅜"	1"

Union Railroad.....	Pronged.		Cut.	Should extend from 1 in. to 1½ in. We use steel ties only on bridges.	 100° A.S.C.E.
Western Maryland.	Corrugated.	Placed by hand and trains seat plate.	Cut.	Should extend outside of base 2 in. and be 7 in. wide. Total area 59½ sq. in.	90° A.S.C.E.
Wheeling & Lake Erie	Goldie tie-plates, Clary M. I. tie-plates.		Cut.	We use 1½ in. on each side, but feel that if area was increased better service would be obtained.	 90° Rail Goldie Tie Plate  90° A.S.C.E. Clary Tie Plate
Yadkin River.....	Longitudinal flanged.	Applied by adzing the tie if necessary and driving plate home with sledge.	Cut.	Should extend 2 in. to overcome side thrust. Total area will depend on the weight of rolling equipment. Heavy, 7-in. x 9-in. plate; light, 6-in. x 8-in. plate.	 70° Rail

Appendix B.

METAL, COMPOSITE AND CONCRETE TIES.

Your Committee was directed to continue the compilation of information as to the use of metal, composite and concrete ties.

During the year the members of the sub-committee dealing with this subject made an inspection of the Simplex steel tie on the C. & A. Ry., the Bates concrete tie on the E., J. & E. R. R., Carnegie steel ties, E., J. & E. R. R., the Universal steel tie on P. & L. E. R. R., Carnegie steel ties on the P. & L. E. R. R., Union R. R. and Bessemer & Lake Erie R. R.

The Committee is building up in your Proceedings a history of the development of the substitute tie. It will be noticed that no ties are reported on unless same have been put in actual use by some steam or electric railroad.

FIG. 1—STEEL SWITCH TIES, ALBION, PA.

The following reports have been received from railroads using substitutes for wood ties, and are submitted only as information to the Association:

Baltimore & Ohio Railroad:

On October 30, 1912, Mr. Earl Stimson, Engineer Maintenance of Way, advised that they have nothing to report.

Bessemer & Lake Erie Railroad:

During the year 1912 this company has purchased 150,000 steel ties from the Carnegie Steel Company. These ties are non-insulated and of the same dimensions as ties previously reported. In addition to this nineteen sets of steel switch ties have been purchased, and attached is a photograph showing a ladder at Albion, Pa., laid with some of these switch ties.

During the year 1913 they expect to use 200,000 steel cross-ties and about fifty sets steel switch ties.

Buffalo Creek Railroad:

Mr. S. M. Kielland, Engineer, advises: "We installed 30 Corell concrete ties on our main eastbound track in 1907." The ties were spaced about 32 in. center to center and under 80-lb. rail. The service is heavy slow freight traffic.

The tie consists of two blocks 8 in. x 9 in. x 30 in. long, held together by a ½ in. x 2½ in. bar. The blocks are made from a steel plate box ⅜ in. metal filled with concrete; two ⅜ in. bolts with suitable clips hold the rail to the tie.

Mr. Kielland further says: "My opinion on this tie is:

(1) The fastenings are too light.
(2) The concrete is of poor quality, shaking to pieces.
(3) The bases of the ties are not large enough.
(4) The two blocks settle often in different directions.

FIG. 2—CORELL TIE, BUFFALO CREEK RAILROAD.

(5) Trackmen have at least twice as much work on these ties as compared with wood ties.

I don't think these ties or similar ones a failure, only a few improvements would make them very practical, especially for slow movements."

Mr. Kielland suggests that these improvements would be as follows: (1) An improved fastening; (2) larger blocks made of high-grade concrete, without any steel cover. Concrte to be reinforced with rods; (3) place ties closer together.

"Having had these ties in our track over five years is evidence of their practical value. Enclosed is a photograph of the ties as they are located in our track. I expect we will remove the ties next year, as the bolts and concrete are wearing out."

Buffalo, Rochester & Pittsburgh Railway:

Mr. E. F. Robinson, Chief Engineer, writes November 13, 1912, as follows:

"The 1500 Carnegie steel ties removed from the main track at Ridgeway, Pa., have been placed in the track at various points, especially at

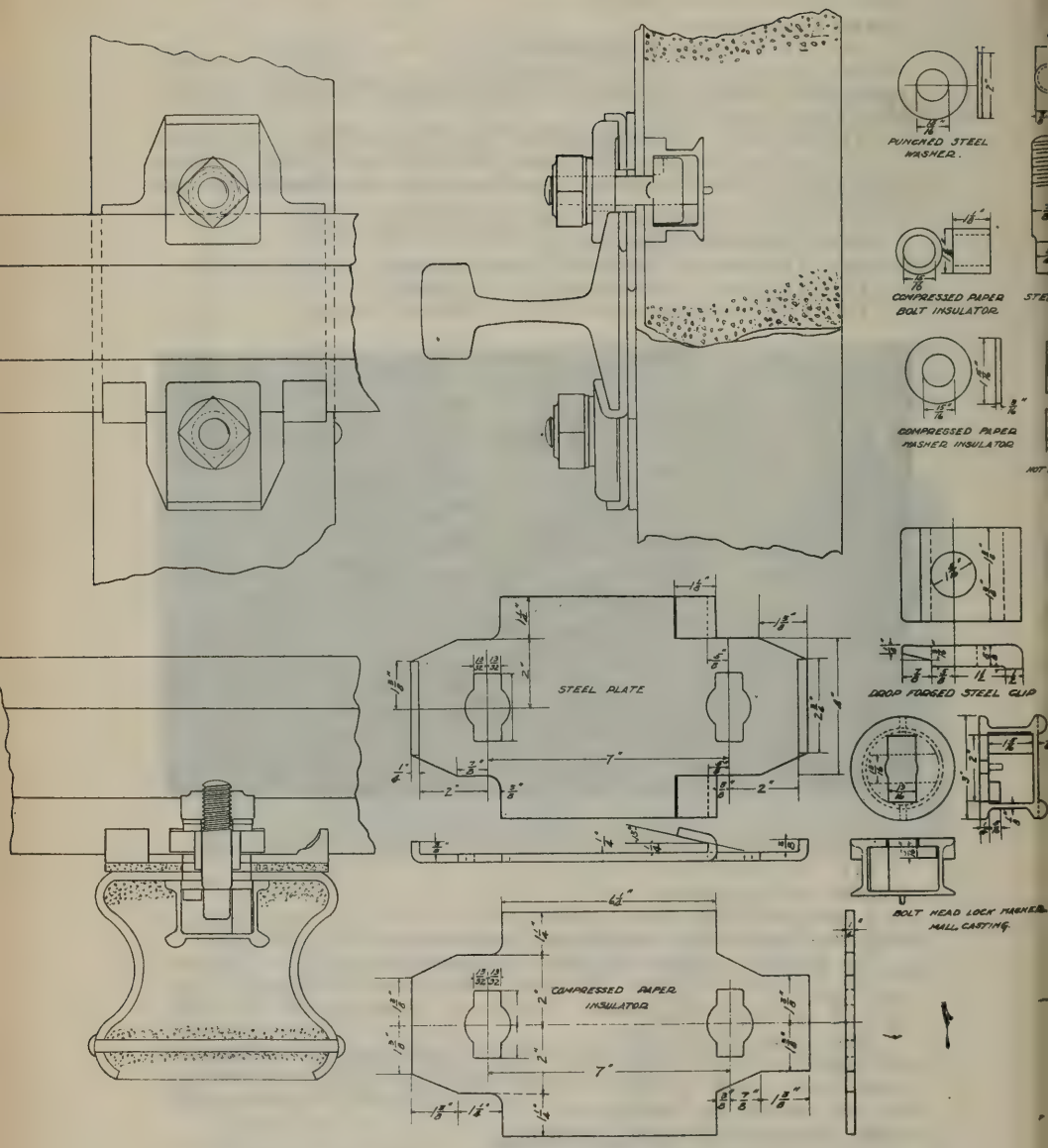


FIG. 3—PLAN OF SIMPLEX TIE.

water stations where locomotive ash pans are cleaned. We have 1500 Carnegie steel ties in the main track at Colden, N. Y., which are giving good service."

Chicago, Burlington & Quincy Railway:

In Vol. 8, page 466, a portion of a report by Mr. E. O. Faulkner to Mr. J. W. Kendrick, then Second Vice-President of the Atchison, Topeka & Santa Fe Railway, mentions some experiments being made by the Engineering Department of the Chicago, Burlington & Quincy Railway.

The Committee asked Mr. W. L. Breckinridge, Engineer Maintenance of Way, in regard to these tests and he advises: "They proved of no value whatever and broke in two and disintegrated. They were considered a complete failure and we have done nothing further in that line."

Cleveland, Cincinnati, Chicago & St. Louis Railway:

Mr. C. A. Paquette, Assistant Chief Engineer, advises that they have not put into use any other substitute ties than the steel ties of which they

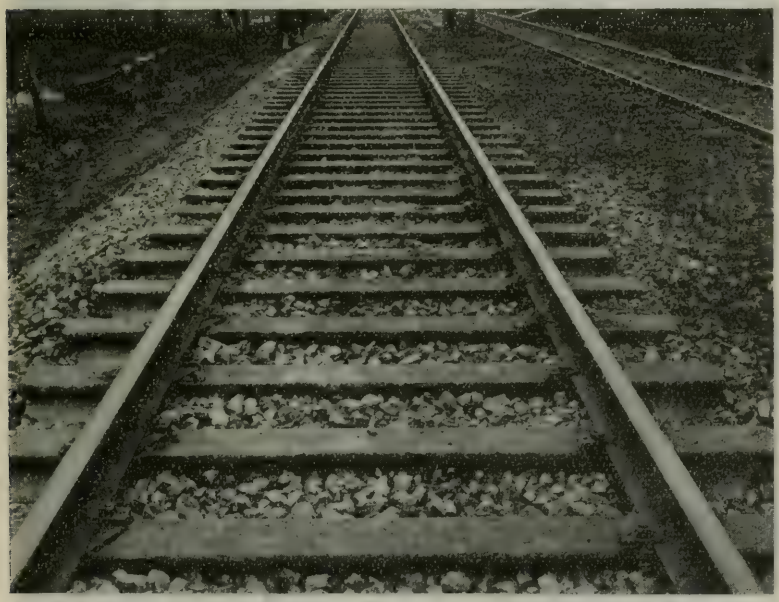


Fig. 4—Chicago Steel Railway Tie Co.—Chicago & Alton Railway.

made a report some years ago. He adds, "These ties are doing very well. I have no criticisms whatever to make of them. It is easy to maintain the track and the opinion of the Section Foreman and Track Supervisor is that the track is kept up with much less labor than with ordinary wooden ties. However, there are not enough of the steel ties in service, there being only one mile of them, to determine just what it costs to maintain track supported on steel ties."

Chicago & Alton Railway:

Mr. H. T. Douglas, Jr., Chief Engineer, advises that they have placed in their northbound main track, a few miles out of Chicago, sixty-three steel ties manufactured by the Chicago Steel Railway Tie Company. He

says: "These ties have been in the track now about four months. They are holding the track admirably to gage, the track is in perfect surface and line, and practically no attention has been given to this track since these ties were installed. * * * They are installed in high speed track and under extremely heavy traffic."

FIG. 5—CHICAGO STEEL RAILWAY CO.—CHICAGO & ALTON RAILWAY.

The Sub-Committee of the Tie Committee inspected these ties on October 14th, and add the following to Mr. Douglas' report. These ties were put in May 7, 1912; are placed under 100-lb. A.S.C.E. rail spaced 20 to a 33-ft. rail. This tie consists of a steel shell shaped as shown in Fig. 3, and filled with concrete. The steel plate weighs about 110 lbs. if $\frac{3}{16}$ in. thick and will weigh about 130 lbs. if ¼ in. thick, the concrete

FIG. 6—DULUTH & IRON RANGE, TOWER JUNCTION—CARNEGIE TIES, INSTALLED 1905, GRAVEL BALLAST.

will weigh about 225 lbs. and the estimated weight of tie complete is from 350 lbs. to 370 lbs., depending on the thickness of the metal used. The tie is insulated by placing a specially prepared tarred paper of fiber under the rail plate and using an insulating thimble around the bolt.

On the Chicago & Alton ties the bolt extends through the upper flange of the tie through to the side of the tie, while the later design is as shown in Fig. 3. In this design a tee bolt is used, the head of which is placed in a hole left in the concrete. A different rail plate is also used on the later design; on this the edges of the plate are turned up providing a stop for the clip to rest against, thus assisting the bolt when the thrust of the rail comes upon it. Figs. 4 and 5 are photographs of the ties on the Chicago & Alton Railway.

Cornwall & Lebanon Railroad:

Mr. A. D. Smith, President and General Superintendent, advises that they have made no further installation of substitute ties since last year's report. He adds, "The Snyder ties are still in our track and are in about the same condition as a year ago. We are not contemplating at this time making further tests of substitute ties."

FIG. 7—DULUTH & IRON RANGE, MILE X 2, CARNEGIE TIES, INSTALLED 1905, GRAVEL BALLAST.

Duluth & Iron Range Railroad:

Mr. W. A. Clark, Chief Engineer, advises: "We have not made any additional installations of steel ties since our last report. Our track laid with steel ties is in too small sections to really get any comparative cost of maintenance, but Roadmaster Shea reports that the steel tie track keeps line and gage better than the wooden tie track, and also, of course, the track keeps in surface better, as we do not have to dig it up every year putting in new ties. Am sending you three prints of steel tie track. You will understand that all of our steel ties are in gravel ballast." Figs. 6 and 7 show this track."

Duluth, Missabe & Northern Railway:

Mr. H. L. Dresser, Chief Engineer, advises: "As to the ties which were reported last year, we are still of the same impression, as they are giving us excellent satisfaction. The only additional steel ties we expect to use in the near future will be one hundred of what are known as the Kimball tie. These were designed by one of our track foremen and he has taken out a patent on the design. He had one made and placed in our track, where it has been for something over a year. We are having

one hundred made at the shops at the present time to put in the track and try out. The idea is to get a tie where a spike could be used without having any wood connected with it."

Fig. 8 shows in detail the design of this tie.

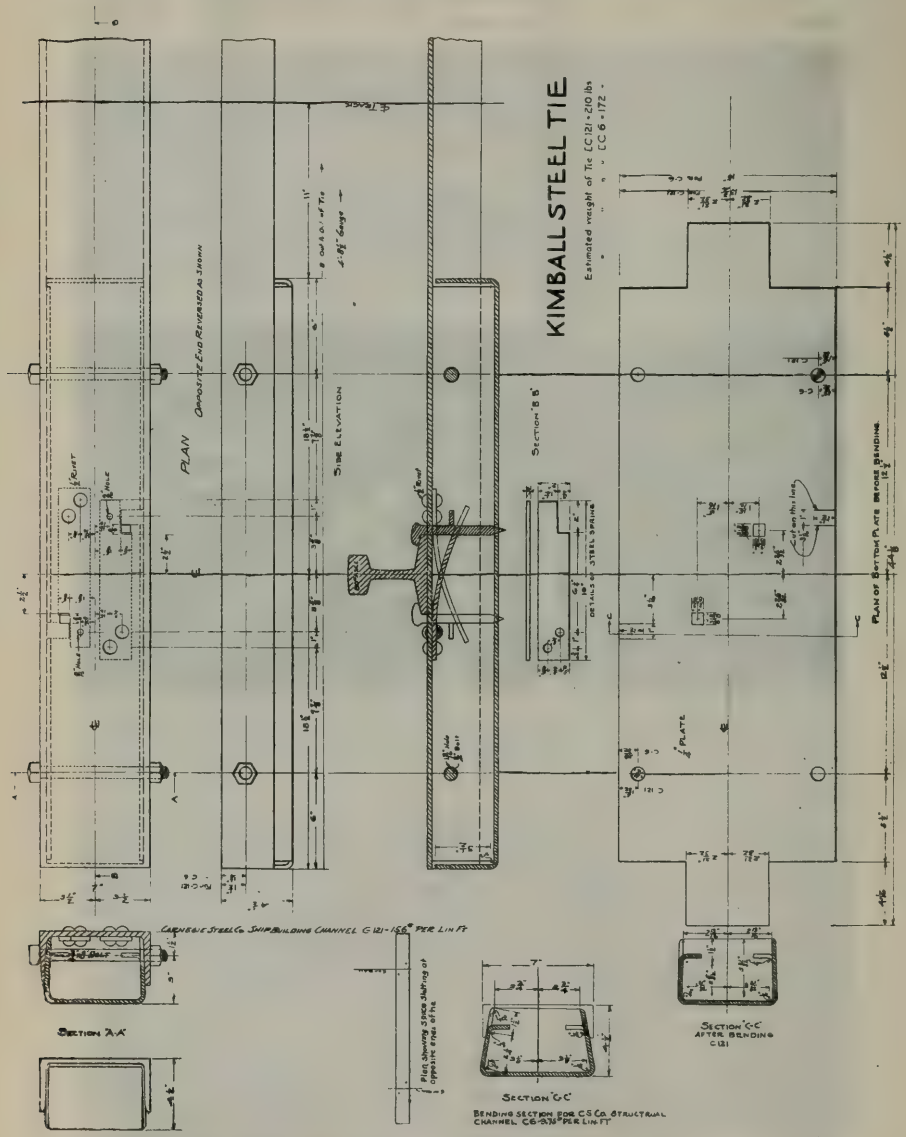


FIG. 8—KIMBALL STEEL TIE, DULUTH, MISSABE & NORTHERN RAILWAY.

Elgin, Joliet & Eastern Railway:

Mr. A. Montzheimer, Chief Engineer, says, "In reference to the use of Carnegie steel ties by this Company, wish to advise that we now have 12,150 Carnegie steel ties in our track, put in as follows: 1907, 50 ties; 1909, 3600 ties; 1910, 7000 ties; 1911, 500 ties; 1912, 1000 ties.

"In addition to the above, we have placed in the track this year 154 sets of Carnegie Steel Company steel switch ties, as follows: 2 sets for No. 16 turnouts; 53 sets for No. 10 turnouts; 3 sets for No. 8 turnouts; 35 sets for No. 7 turnouts; 20 sets for No. 6 turnouts; 10 sets for No. 5 turnouts; 31 sets for No. 4 turnouts.

"We are very much pleased with these ties and find that expenditures for surfacing and lining tracks are less when these ties are used than where we have wooden ties. Steel ties are especially good on curves and I find that our men have, wherever possible, distributed steel ties around our sharp curves to hold the track to gage. There is no chance for track to spread on steel ties. On one mile of steel ties that were put in in 1909, the clips and bolts have not been tightened since they were given their final tightening two weeks after the ties were installed.

"Our experience with Carnegie steel ties has been satisfactory in every way and I expect in the future we will use a great many of these ties. We are planning to put in 91,000 of these ties next year."

This Company has also installed 62 reinforced concrete ties designed and manufactured by Mr. A. J. Bates, Chicago. These ties are in their eastbound main at Whiting, Ind., placed under 80-lb. A.S.C.E. rail spaced 22 to a 33-ft. rail in stone ballast. They were put in the track May 1, 1912. Fig. 9 shows in detail the design of this tie and Fig. 10 is a photograph of same in the track and Figs. 11 and 12 are photographs of an exhibition tie. Mr. Bates' system of reinforcement was designed to meet the following conditions: (1) Low cost; (2) ability to stand rough handling; (3) possibility to allow concrete to flow through its openings and create one solid mass of concrete without being sufficiently separated by the reinforcement to materially weaken the bond of the concrete, such as would exist if the reinforcement consisted of steel plates, I-beams, channel irons or old rails. All such types of reinforcement cut the concrete in two to such an extent that there is not sufficient bond left to hold the concrete in one solid mass.

As will be seen from the drawings, the reinforcement consists of two parallel trusses made by slotting and expanding specially rolled steel shapes, about which are cast on either end blocks of concrete 34 in. long, 9 in. wide and 7½ in. deep, leaving the reinforcement exposed at the center. There are two types of fastening; one, which consists of a wooden plug driven behind a spike with a hooked end, and the other consisting of a wooden plug driven behind a hook bolt. The Sub-Committee inspected these ties October 14, 1912, and found the ties as shown in the photographs. These ties weigh 450 lbs. each.

Erie Railroad:

Mr. H. H. Althouse, Chief Engineer, furnished the Sub-Committee the following reports:

Mr. H. O. Dunkle, General Superintendent, says: "In regard to test of metal ties installed at Jamestown and Cleveland: Those at Jamestown are giving good service and we have no cause for complaint. Those at Cleveland are likewise giving good service, having been applied at Literary Street Yard. There has been no trouble maintaining track or holding it to gage on account of bolts shearing off. Altogether would say that they are giving good satisfaction." The ties at Jamestown are Carnegie steel ties, I-beam section laid under 90-lb. rail within the platform and are covered with brick paving; 280 ties were installed September, 1909.

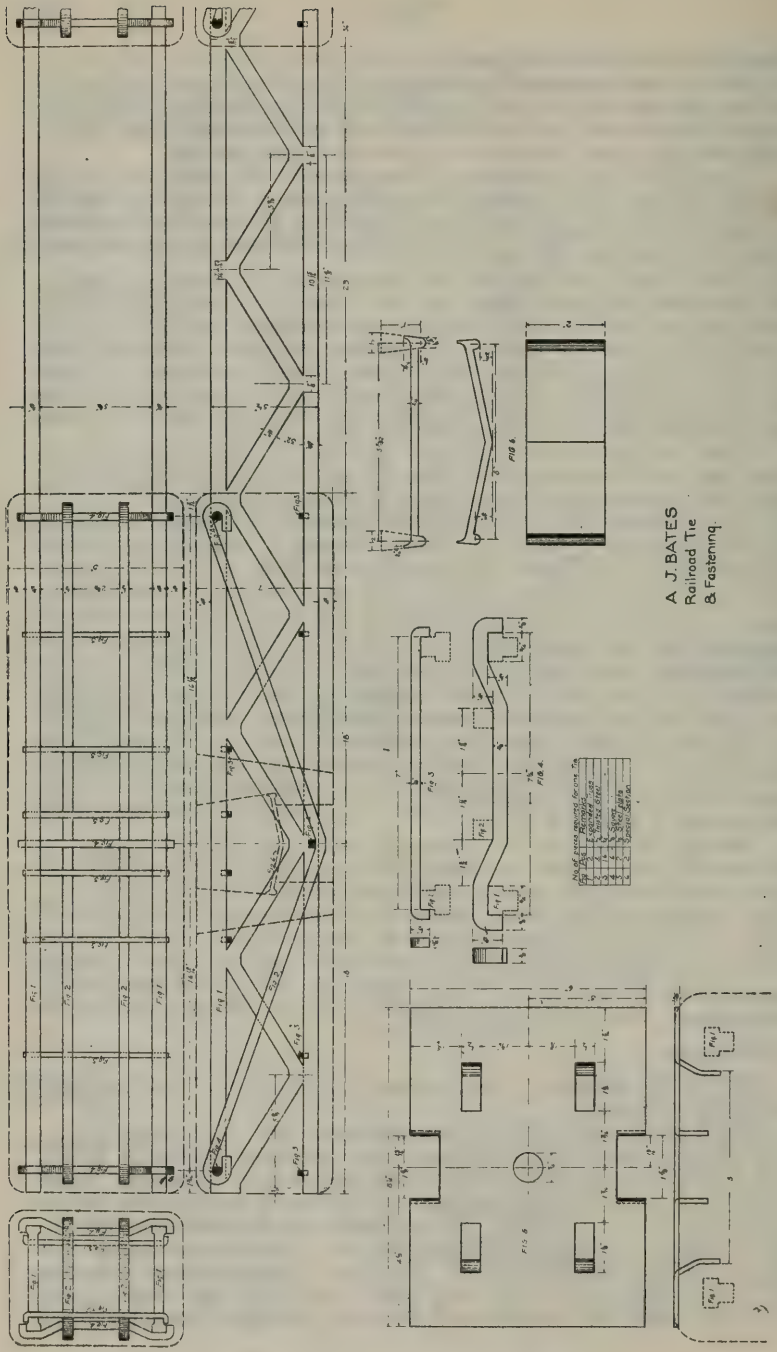


FIG. 9—BATES CONCRETE TIE.

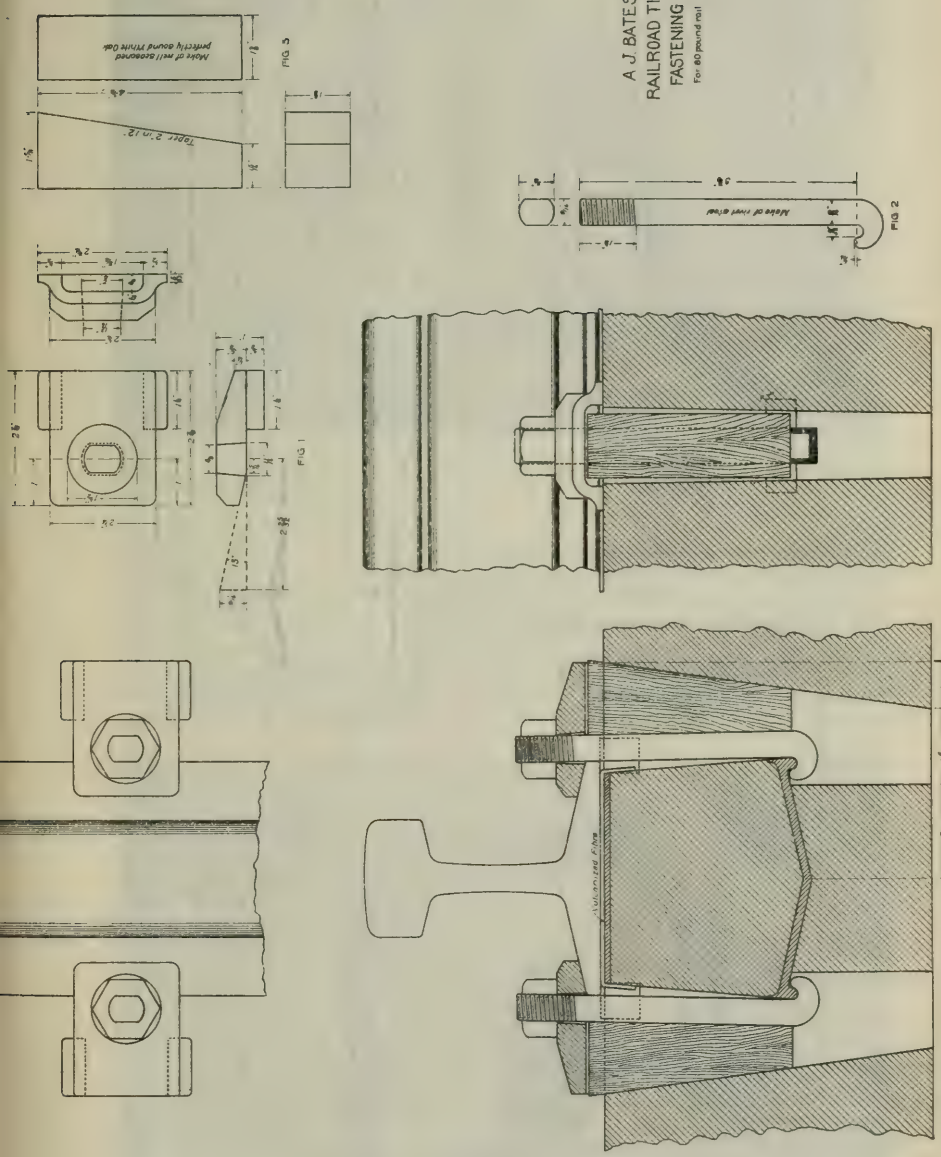

A J BATES
RAILROAD TIE
FASTENING
For 80 pound rail
FIG. 1
FIG. 2
FIG. 3

FIG. 9A.

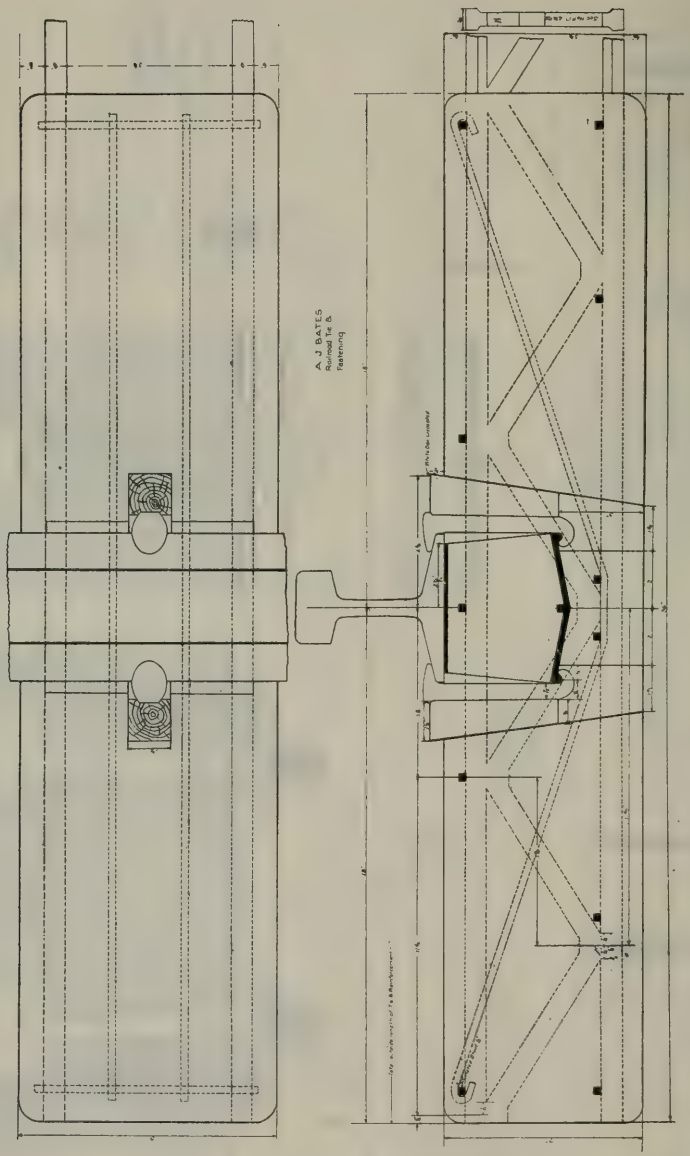


FIG. 93.

FIG. 10—BATES CONCRETE TIE, WHITING, IND., ELGIN, JOLIET & EASTERN RAILWAY.

The ties referred to at Cleveland are a No. 10 steel switch set (Carnegie I-beam section) under 90-lb. rail installed May 30, 1909."

Mr. A. J. Stone, General Superintendent, advises: "We have made no further installation of ties of this character since my report September 15, 1911. Therefore the Carnegie steel switch ties at Croxton are still the only ties of this description in use. The original 57 ties are still in service, although one additional tie, or a total of two ties, has now broken. Both of them are still in service. The second tie broken broke in the same way as the tie mentioned in my letter of September 15, 1911, and the

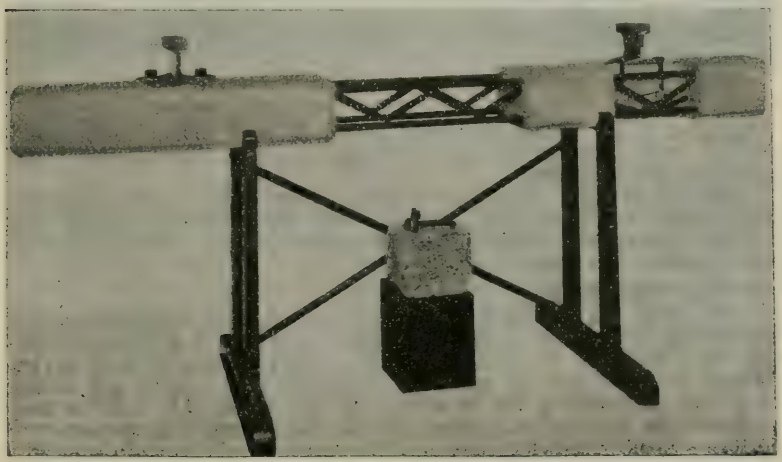


FIG. 11—BATES CONCRETE TIE.

break is attributed to the same derailment. There is, however, no positive proof that such is the case, but it is the opinion of the foreman in charge of this section, also the Supervisor.

"All of these ties are rusting and depreciating greatly by exposure to the salt air prevailing in this locality. It is necessary to keep constantly renewing the bolts in the clips fastening these ties to the rail, as the holes in the ties are rusting and consequently they are getting larger than the bolts, and the metal is becoming thin. If this depreciation continues as fast in the future as it has in the past, the failure of a good many of these ties through the bolt holes is expected in the near future.

"These ties have now been in since April 15, 1909, and it is difficult to advise as to their worth as compared with yellow pine ties until they have been in service at least as long as a yellow pine tie would last, which should be from seven to ten years, but thus far they have not indicated any pronounced improvement."

Florida East Coast Railway:

Mr. E. Ben Carter, Superintendent Maintenance of Way, advises: "We installed in March, 1906, 16 Percival concrete ties on our line at St.

FIG. 12—REINFORCEMENT, BATES CONCRETE TIE.

Augustine, Fla." These ties were placed in sand ballast under 70-lb. A.S.C.E. rail spaced 16 ties to a rail length (30 ft.). Twenty-four trains pass over these ties daily.

Mr. Carter says, "An examination of them October 22d shows they are in good condition in all respects. The fastenings are holding well and have never been touched since they were put on." See Fig. 13 for photograph of this track.

Hocking Valley Railway:

Mr. Wm. Michel, Chief Engineer, advises that 16 International steel ties were placed in their northbound freight track near Rich Street, Columbus, Ohio, last year, at which point they receive exceptionally hard service. "These ties have been in the track practically nine months and during that time no surfacing has been done at that point. The track is now somewhat in need of smoothing up. Of the sixteen ties, the concrete in ten of them is showing signs of disintegration and three of them must be taken out soon on this account."

Galveston, Harrisburg & San Antonio Railway:

This Company under date of October 24th, advises as follows: "In reply to your inquiry for a further report as to the concrete ties we have installed in Test Tie Track at Bayou Sale, La., and Edgewater, Tex., beg to advise that no material change has occurred at Bayou Sale test, over report sent the Committee last year.

"As to the Edgewater test, of the 52 ties laid continuously there was one broken (but not removed) during the year.

"As to the 43 ties interspersed with cypress ties, three concrete ties are reported broken. We have made no new installations of concrete ties during the past year."

Lake Terminal Railroad:

Mr. F. W. Waterman, Engineer, says: "The only additional information that we can furnish at this time is that we expect to install 17,000 steel cross-ties and 3000 steel switch ties in the standard gage track and 500 steel cross-ties and 220 steel switch ties in the narrow gage tracks of the National Tube Company during this year." (Ties referred to are Carnegie Steel Co. I-beam type.)

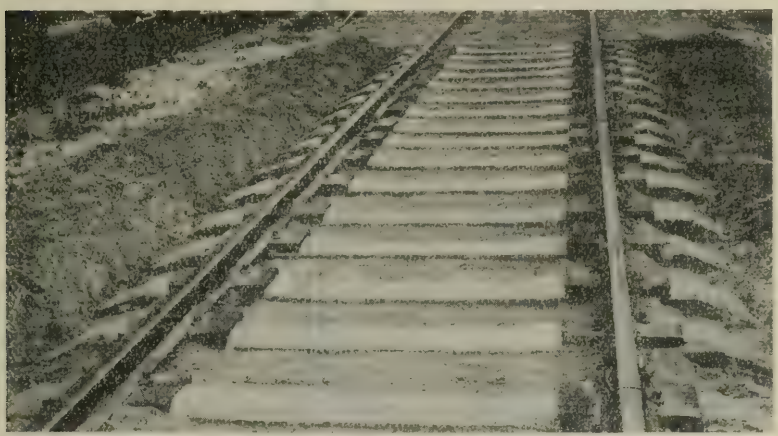


FIG. 13—PERCIVAL CONCRETE TIES—FLORIDA EAST COAST RAILWAY, ST. AUGUSTINE, FLORIDA.

"Since our last report on this matter, we have changed the tie clips and bolts so that we are now using an oblong hole in the clip and an oblong shank on the bolt, which we find gives us greater strength and also prevents the clip from turning." (For plan of bolt and clip, see Bessemer & Lake Erie report, Vol. 12, Part 1, page 372.) "We have applied these on sharp radius curves where we are using our Mallet compound locomotive with a total weight of 360,000 lbs. on twelve drivers, the total driving wheel base of which is 29 ft. 8 in. with a wheel base of 10 ft. 0 in. each for the high pressure and low pressure engines, and are having no trouble with broken bolts."

Midvale Steel Co.:

This company advises that they have about 2600 "Snyder" ties in yard tracks at their works, Midvale, Pa.; 600 installed in November, 1907, 1000 in July and August, 1909, and 1000 in September, 1912. The traffic is

ordinary yard service at slow speed. For design of this tie see Vol. 13, page 352.

Norfolk & Western Railway:

Mr. W. H. Coffman, Bluefield, W. Va., advises he constructed about 1909 a siding to a stone quarry on the line of the Norfolk & Western Railway, near Bluefield, in which he has used the form of construction shown in Fig. 14.

In this system the solid bed of ballast is expected to provide against settlement. The gage is maintained by flat steel tie bars which grip the base of each rail and these bars are anchored in the ballast to preserve alignment. The rails are supported at the joints by short pieces of steel channels, but otherwise they bear directly upon the specially prepared ballast.

For heavy traffic Mr. Coffman says the ballast should be 18 in. to 24 in. deep, and material should be crushed limestone, which should be run of crusher (no piece larger than 2½ in.) to a thickness of 4 in. for the first layer. This is rolled with a steam roller. Then another layer is spread and rolled and so on until the desired thickness is reached.

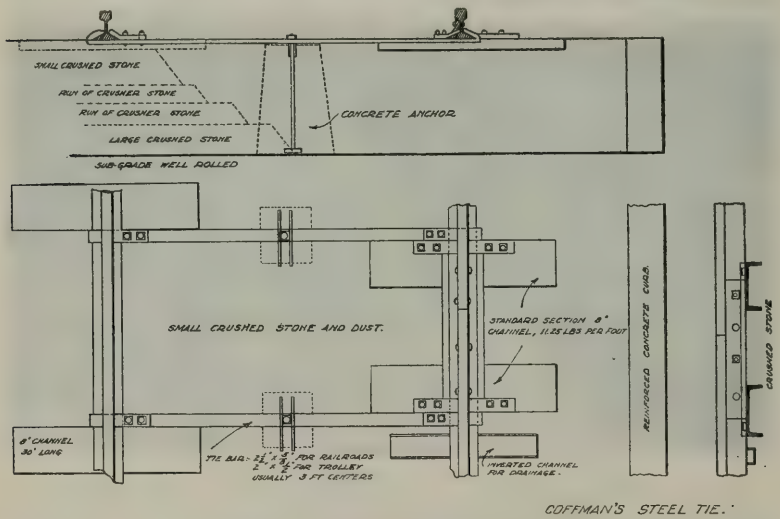

SMALL CRUSHED STONE
RUN OF CRUSHER STONE
RUN OF CRUSHER STONE
LARGE CRUSHED STONE
SUB-GRADE WELL ROLLED
CONCRETE ANCHOR
SMALL CRUSHED STONE AND DUST.
STANDARD SECTION 8" CHANNEL, 11.25 LBS PER FOOT
REINFORCED CONCRETE END
CRUSHED STONE
8" CHANNEL 30' LONG
TIE SIZE 2½" x 8" FOR RAILROADS 2" x 8" FOR TROLLEY USUALLY 3 FT CENTERS
INVERTED CHANNEL FOR DRAINAGE.
COFFMAN'S STEEL TIE.

FIG. 14—PLAN SHOWING COFFMAN SYSTEM TRACK CONSTRUCTION.

The rails are then laid on blocks and channels and tie bars attached to them, after which the track is let down on the prepared bed and lined. Holes are now dug in the bed for the anchors and slots are made in same so that the legs of the channels will settle and allow the face of the channel to rest on the stone surface. The track is given a final lining, after which the anchors are placed and cemented in.

Pennsylvania Railroad:

Mr. L. R. Zollinger, Engineer of Maintenance of Way, says: "Replying to your letter of 6th inst., relative to substitute ties, beg to say that we have practically no further information on this subject now than at the time of writing my letter to you of August 30, 1911.

"The steel switch ties referred to in above-mentioned letter were installed in Pitcairn Yard, Pittsburgh Division, October, 1911, and so far

are satisfactory, but have not been in service long enough to determine whether they will prove worth their higher cost as compared with wooden switch ties.

"We have also installed experimentally on the Low Grade Division at Atglen, Pa., some ties made from old rails, but their service has also been of too short duration to permit of any conclusions as to their merits."

Pennsylvania Lines, Northwest System:

Mr. Robert Trimble, Chief Engineer Maintenance of Way, advises September 23, 1912, as follows in regard to substitute ties on their lines:

"Riegler Concrete Steel Tie.—These ties are still in good condition. One tie which had contained a poor batch of concrete was repaired about 18 months ago and is now perfectly sound. The track fastenings are in good condition. There has never been any trouble with the automatic signals by interference of these ties with the track circuits. Line and surface is maintained with less work than with wooden ties.

"Rohm Steel Ties.—Twelve of these ties were put in eastbound freight track, east of Sewickley, Pa., on June 15, 1910. This tie is trough-shaped, and is made of ⅜ in. steel. It is 8 ft. 6 in. long, 9⅝ in. wide on the bottom and 7⅝ in. wide on top. The rails rest on wooden blocks and are held in place by steel cover-plates, which are fastened to the body of the tie by wedges. The ties are all in good condition, except one tie, which shows a slight crack in the holding plate outside the rail. The Supervisor thinks they take a little more work to keep in line than the wooden ties, and require about the same amount of surfacing. It is necessary to tighten the wedges about once a month.

"Universal Metallic Ties.—One hundred of these ties, furnished free by the manufacturers were placed on a curve in the eastbound freight track west of Emsworth, Pa., in December, 1910. This tie is a rectangular trough 8 in. wide x 4 in. deep x 8 ft. long, made of ⅜-in. steel. The bottom of the tie is slotted and four pieces of metal (two under each rail) 3½ in. x 3¼ in. are turned up, forming two seats to hold wooden blocks on which the rails rest. The rails are held in place by steel clips, which are held in place by bolts passing through the turned-up flanges and the wooden blocks. A fiber insulation is used under the clips. The ballast fills the troughs, as well as the space between ties. These ties are all in good condition. The cost of maintenance of this track is considerably higher than of an equal adjoining length of track with wooden ties. The cost of lining and surfacing from December, 1910, to May, 1912, was, for the metal ties $203.91 and for the wooden ties $55.08."

For design of this tie, see Vol. 13, page 356.

Pennsylvania Lines, Southwest System:

Mr. W. C. Cushing, Chief Engineer of Maintenance of Way, has given the Committee the following information:

Chenoweth Concrete Tie.—(See Vol. 12, page 382, for details in regard to these ties.) To this Mr. Cushing adds: "On June 2, 1911, six removed; on August 15, 1911, one removed; on June 5, 1912, 26 were still in the track, of which none were joint ties, three shoulder ties, and 23 intermediate ties. The three shoulder ties were broken, two at one end and in the middle, and one at one end only. Of the 23 intermediate ties, two were in good condition and 21 broken.

"With the exception of the two good ties, all of these ties would have have been removed had they not been placed in a low-speed track and so interspersed with wooden ties that the track was considered safe. It will no doubt be necessary to remove them by the end of this year."

Brukner Concrete Ties.—(See Vol. 12, page 382, for previous report on these ties.) To this Mr. Cushing adds: "On June 21, 1911, twenty new Brukner ties of somewhat heavier design than those previously in-

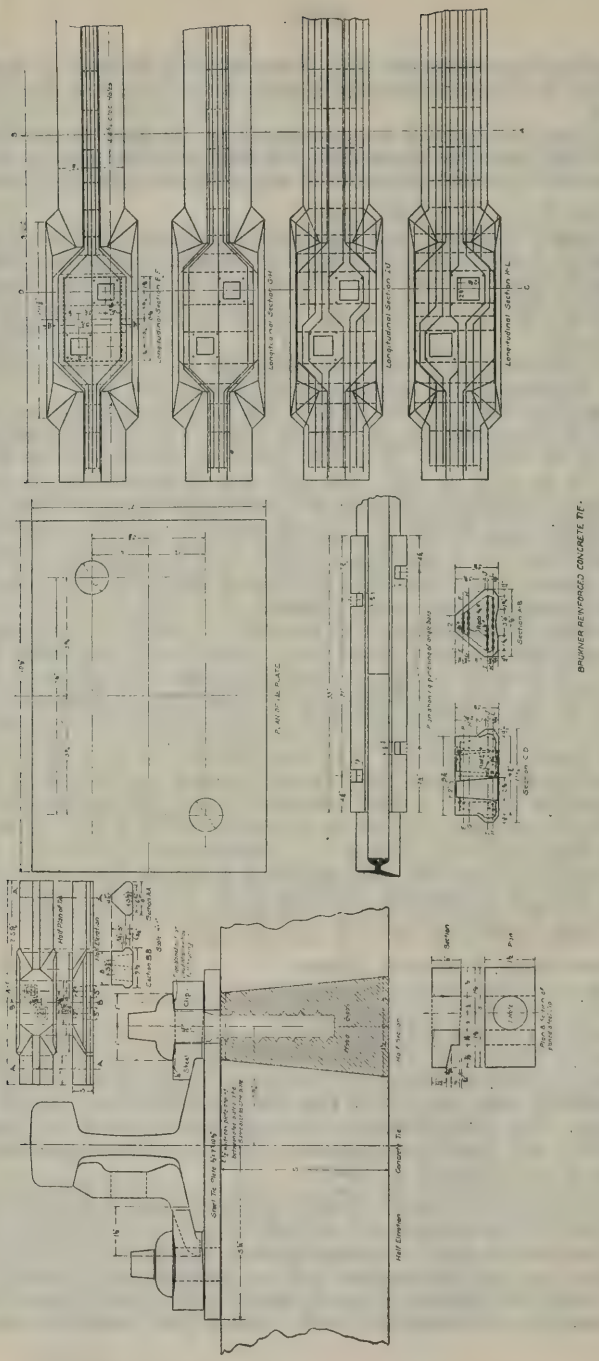


FIG. 15—BRUKNER TIE, P. C. C. & ST. L. RY.

stalled were placed in track and seven old ones removed, as they were broken. On November 29, 1911, eight of the new ties were removed on account of failure, and on December 1, one. One was also removed between December 1, 1911, and May 21, 1912, the exact date not being known. Of the eleven ties in track May 21, one was a joint tie, two were shoulder ties, and eight intermediate ties. The joint tie was crushed under the rail and broken in the middle. One of the shoulder ties was

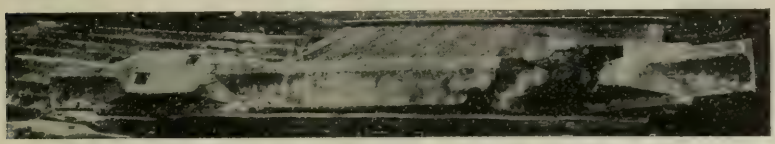


FIG. 16—BRUKNER TIE, BROKEN IN SERVICE—SCULLY YARD, P. C. C. & ST. L. RY.

in good condition and one broken inside of the rail and cracked in the middle. Of the eight intermediate ties, one was broken at change of section, just inside of both rails; one broken inside of one rail and cracked in the middle, one broken inside of one rail, and four cracked in the middle.

"The above shows that at the end of eleven months 95 per cent. of the ties had failed, and 45 per cent. had been removed from the track of the heavier section. All of the ties would have been removed in May, had it not been that they were in a slow-speed track, and distributed between wood ties."

On November 1, 1912, Mr. Cushing advises that all of the Brukner ties have been removed on account of failure. Fig. 15 gives a detailed plan

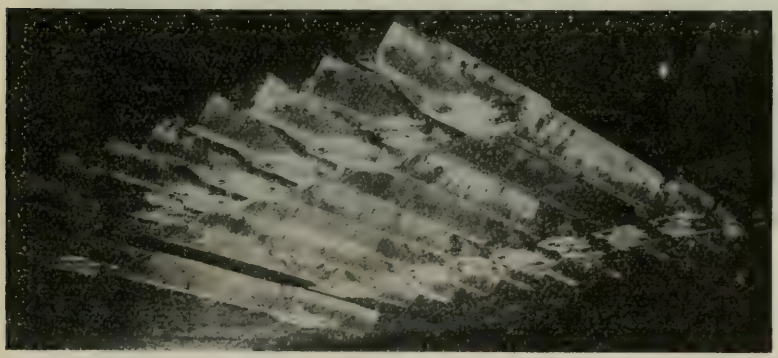


FIG. 17—BRUKNER CONCRETE TIES, P. C. C. & ST. L. RY.—TIES REMOVED FROM TRACK, SCULLY YARD.

of this tie and Figs. 16 and 17 are photographs of the ties after they were removed from the track.

Kimball Concrete Tie, patented by Geo. H. Kimball, Consulting Engineer, Detroit, Mich.—This tie consists of two blocks of concrete, three feet long, seven inches deep, nine inches face with curved sides, connected by two 3-in. by ¼-in. by 8-ft. channels placed back to back, two inches apart, and bolted. The rail rests on 3-in. hardwood blocks, anchored in

the concrete and secured by spikes driven through said blocks into elm plugs imbedded in the concrete. See Fig. 18.

One sample tie, as above, was installed in a slow-speed running track in Scully Yard on November 21, 1911. In May, 1912, the date of the last report, the tie showed no signs of failure.

Pittsburg & Lake Erie Railroad:

Mr. Edwin F. Wendt, Assistant Engineer, furnishes the following information:

"Carnegie Steel Ties with Wedge Fastening.—The six ties in westward main track at Pittsburg Terminal Station were placed in May, 1908. and are still in the track. The Supervisor reports track to be in good line and surface. Have had no trouble from insulation. It has been found to be impossible to keep wedges tight.

"Carnegie Steel Ties with Bolt and Clip Fastening.—These ties, 3000 in number, were laid in westward freight track at McKee's Rocks, Pa.,

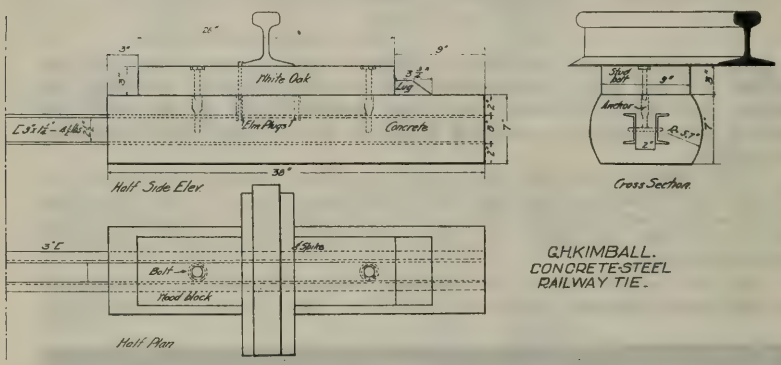


FIG. 18—KIMBALL CONCRETE AND STEEL RAILWAY TIE.

in August, 1907. As previously reported, an experiment is being conducted to determine the comparative maintenance expense in connection with 3000 steel ties and 3000 white oak wooden ties, the one stretch following the other in the same main track under similar conditions. The comparative statement as of December 31, 1912, shows annual cost of maintenance, as follows:

Calendar Year.	Length of Experimental Track Section. (feet)	Carnegie Steel Ties.	White Oak Ties.
1908	4,400	$280.00	$417.00
1909	4,400	153.00	95.00
1910	4,400	428.00	128.00
1911	4,400	184.00	116.00
1912	4,400	348.30	94.00

"These costs for 1912 are made up as follows:

Labor surfacing and lining steel ties	$239.80
Labor renewing fibers on steel ties	6.50
1,000 new fiber plates on steel ties	102.00
Total cost of maintenance of steel ties	$348.30
Labor surfacing and lining wood ties	94.00

"These experimental sections of track were built with new material and new limestone ballast in 1907.

"The record of cost begins with calendar year 1908.

"The ties are laid in main line westward freight track, equipped with electric circuits in connection with automatic signals.

"Speed of freight trains 30 miles per hour.

"It is now, December 31, 1912, 64 months since these steel cross-ties were laid in track and the record of the fiber insulation shows that none were renewed previous to 1911 and only 17 were renewed in that year and only 1000 in 1912.

"There has been, practically speaking, no signal trouble whatever.

"Universal Metal Tie.—One hundred of these ties were placed in westward main track, Pittsburg, February, 1911. Track is in good line and surface at present. A few bolts were found to be loose during the year.

"Labor during 1912 for surfacing these ties, $22.15.

"Atwood Concrete Steel Tie.—Five ties of this design were placed in No. 4 westward main track, McKees Rocks, Pa., in October, 1908. This track is used by high-speed passenger trains. Ties are in good condition and track is in good line and surface. There are no indications of fractures. No trouble from insulation.

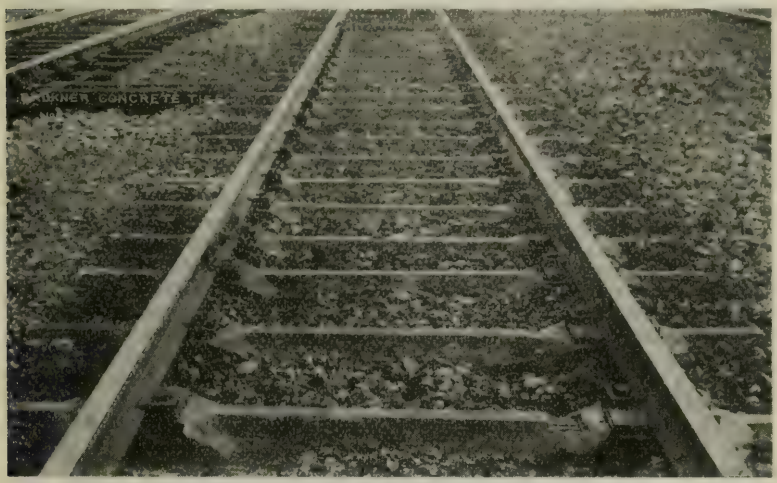


FIG. 19—BRUNKER CONCRETE TIES, P. & L. E. R. R.

"Brukner Reinforced Concrete Tie.—Twenty of these ties were placed in track October, 1911. At the present time all of these ties are fractured, as indicated by photograph which is made a part of this report. Two ties under joints are badly fractured and the concrete is coming loose from reinforcement. Screw spike fastenings were tightened down once since being originally placed."

Pittsburg, Shawmut & Northern Railway:

Mr. H. S. Wilgus advises that they have purchased no new substitute ties since his last report, nor are they expecting to do so in the near future. He adds, "The ties in the track have thus far given eminent satisfaction."

In regard to loss of weight in these ties, Mr. Wilgus says, "It is safe to assume the loss per year in cinders approximates 4½ lbs. and the loss in gravel .7 lb."

Union Railroad:

Mr. W. S. Gibson, Engineer Maintenance of Way, advises: "Since my last report we have ordered 71,000 steel cross-ties not insulated, 240 sets of steel switch ties and 300 insulated steel cross-ties with the wedge or Slick fastenings. (For design of this fastening see Vol. 10, page 504.) These ties are all in the track except about 35,000 steel ties, 110 sets of steel switch ties and 300 insulated steel cross-ties with wedge fastenings which the mills have not been able to roll for us on account of orders booked ahead of ours.

"On June 9, 1908, we ordered 5,000 steel cross-ties with the wedge fastening, 4,000 non-insulated and 1,000 insulated, which are all in the track and in very good condition, except possibly a few which were damaged by a derailment. We have not ordered or bought more than 2,000 wood cross-ties nor more than 25 sets of wood switch ties since June, 1906."

Altoona & Logan Valley Electric Railway:

Mr. F. D. Hain, Superintendent of Construction, advises as follows: "Replying to your inquiry of the 4th inst., relative to the use of International Steel Ties, beg to advise that in August and September, 1909, we installed 175 of these ties as a favor to the inventor, Mr. Day, he being a resident of this place, and he furnished to us the tie complete and ready to install, but we installed same with our own track forces. Unfortunately, we do not have any plans showing the details of same. In addition to the above, we purchased but only installed a few of a very similar tie to be used in paved streets in connection with Carnegie ties, the whole to be concreted and grouted in place, and the International tie was used under the joints only, with Carnegie between, the latter being on about 4 ft. 7 in. centers.

"The first 175 were installed on two curves with a total length of about 700 ft., the installation of the ties being on about 4-ft. centers, but as the top plate is 28 in. long, it left about 20 in. between ties, but the distance varied on account of joints running ahead on the curve. About two-fifths are under 70-lb. rail and the other three-fifths under 60-lb. rail, both A.S.C.E. sections. The curves are spiraled with about 11 degrees center radius, have 6 in. elevation, and are run at a speed of 20 to 30 miles per hour. Under the lighter rail there is a descending grade of about 3 per cent. Both locations full stone ballasted with six or more inches of ballast under the tie. Rails are 30-ft. lengths.

"The tie consists of two 5 in. standard I-beams spaced 24¾ in. center to center, with a 12 x 28 in. plate centered under each rail. Three fasteners on each side of each rail, making six fastenings for each rail for each end of tie. (This makes it a little stiff for sharp curves and hard to line.) Tie was cast full of concrete the full height of I-beam and as wide as top plate, and at my suggestion a 1½ by 1½ angle was riveted to lower flange of I-beam to keep tie from spreading, but more particularly to give a solid place against which to tamp, as the raw edges would soon round off the concrete, if not entirely break the concrete under heavy tamping. The actual tie-supporting area can be enlarged by making the sides of the concrete sloping instead of vertical. You will observe that the tamping of this tie is lengthwise of the rail, instead of across, same as with a wooden tie. The concrete supplied in this particular instance was very poor and a few of the ties do not show up very well, but the balance of them are holding very well and not more than one or two of the fastenings have worked loose. The fastenings furnished are not as good as those of later type, but both the new and old type consists essentially of a U-shaped malleable casting, with opening of U in horizontal position, with a wedge to drop in behind one of the clips on the same hand at each end of tie. To install

the tie, the clips on same hand at each end are set in place, the tie shoved against the rail, opposing clip set in and wedge driven, after which both sets of holes are grouted in place. It is very simple and more rapid than spiking up wooden ties. It is evident that the tie must be very carefully detailed to get proper gage and lacks adjustability to allow for worn rails, after once grouted in place, but the use of them at this place leaves nothing to be desired as to surface, line, holding to gage, etc. In fact, the tie has given very good results, and it is only the cheapness of wooden ties that prevents our purchasing more of them. The tie costs from $5.00 to $6.00 each for the pair, depending altogether on the weight of metal used and current tonnage prices. This will give a cost per actual tie, comparing with wooden or other types of ties, of half the above.

"The traffic over our installation is about 190 twenty-three-ton cars per day, largely augmented during summer months by single truck park cars."

Chicago City Railway Company:

Mr. H. B. Fleming, Vice-President, says, "I hereby acknowledge receipt of your letter of September 26, 1912, regarding steel ties, and in reply desire to advise that we are laying at the present time one mile of track with Carnegie steel ties on Forty-seventh Street, from Paulina to Leavitt Street."

Cleveland Railway Company:

Mr. Chas. H. Clark, Engineer of Maintenance of Way, says: "During the year 1910 we placed in open track about one mile of International Steel Tie Company's twin ties, using eight to a 33-ft. rail length, placing them 46-in. centers, the tie having a longitudinal bearing of 32 in. These tracks were lifted about two feet from the old bed and filled in with stone ballast. We have both city and interurban cars operating over this track. We have not as yet touched same from the time they were installed. The clips that fasten the rail to the tie are in the best of shape, and after close examination I could not find any indications of even one clip being loose on the entire stretch. The cars operating over this stretch of track ride very smoothly. We have been using quite a number of the Day twin ties in our closed track work, using them entirely underneath the joints last year and this spring, but in all our work this fall we have placed these ties 6-ft. centers with a concrete foundation. I consider this the best method of laying tracks in paved streets that I have yet undertaken."

Cleveland, Southwestern & Columbus Railway:

Mr. J. A. Nestor, Superintendent, advises: "Your favor of the 4th inst., asking for information regarding steel ties at hand. Note below answers to your questions:

"Weight of rail, 1,800 ft. of 7-in. 70-lb. tee rail;

"Weight of rail, 1,800 ft. of 9-in. 90-lb. girder rail;

"Spacing of tie, 3 in.;

"Kind of ballast, concrete;

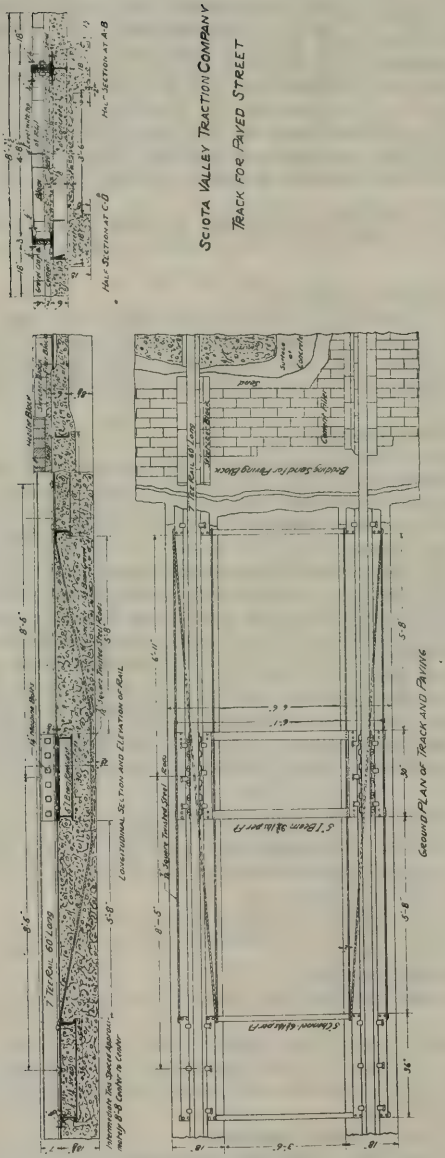
"Number of ties installed, 600 twin ties (International Steel Tie Co.'s ties).

"Twenty-minute service over these tracks with 35-ton cars.

"Tie rods used on the 9-in. girder rail. These ties cost but very little more than good oak ties, and in my judgment are the only thing to use in a paved street."

Columbus Railway & Light Company:

Mr. E. O. Ackerman, Engineer Maintenance of Way, advises: "Replying to yours of September 26, relative to data concerning steel ties installed by us, I wish to say that we have no further information than


SCIOTA VALLEY TRACTION COMPANY
TRACK FOR PAVED STREET
Half Section at A-B
Half Section at C-D
Bedding Sand for Paving Block
Concrete Filling
Asphalt Block
Grout Filler
Asphalt Base
Steel Rail 60 Lbs.
Steel Tie
Steel Tie
Steel Tie

that given you last year. We are, however, experimenting with a new type of rail fastener and may give you some interesting data later on."

International Railway Company (Buffalo, N. Y.):

Mr. E. G. Connette, Vice-President, advises: "We have Corell concrete ties, with iron connecting rods, installed on our Lockport Division, in 180 ft. of track, ballasted with crushed stone, with a top dressing of gravel. There are 61 ties, in all, spaced at 3-ft. centers, and were placed in the track on April 18, 1908. They carry an 85-lb. A.S.C.E. tee rail. Thirty-eight-ton (loaded) cars operate over this track every 15 minutes at an average speed of 25 miles per hour."

The Committee have been unable to get plan of this tie, but Fig. 2 is photograph of the same tie on the Buffalo Creek Railroad.

Lake Shore Electric Railway:

Mr. A. V. Brown, Engineer Maintenance of Way, under date of October 5, 1912, says: "In answer to yours of the 26th, regarding use of steel ties during 1912, would state our system has installed this year at Genoa, O., approximately one mile of track in pavement, using 100-lb. A.R.A. rail, Carnegie M-25 ties, intermediate, with M-25 fastening and International Steel ties for the joints. Sub-foundations not less than 6-in. concrete mixture 1-3-5. This work has been recently completed and so far has developed no weaknesses. This gives us a total of approximately 2½ miles of track with the use of steel ties, all of which is giving entire satisfaction to date."

New York State Railways:

Mr. D. P. Falconer, Engineer Maintenance of Way says: "Replying to yours of the 26th inst., with reference to the use of steel ties, we have not, up to the present time, used steel ties with any other type of construction aside from that outlined in Mr. Tilton's letter of November 22, 1911—that is, all-steel ties, which we have installed have been in city streets with concrete ballast and concrete between the ties for the pavement. The length of time which these ties have been installed is not sufficient to warrant a fair comparison between these ties and the wooden ties. The indications are, however, that this type of construction for city streets is very satisfactory."

Scioto Valley Traction Company:

Mr. A. J. Wolfe, Chief Engineer, advises: "In answer to your letter of September 26, asking for information as to the International Steel Tie which we have used in our track construction, we are sending you herewith a blueprint, showing this construction as used. This track has been in service for a year and one-half, and while it has passed through the most severe winter known in this section of the country, there has been no sign of deterioration in any way whatever. The joints in the track, even when the thermometer was below zero, were only to be found by very close inspection.

"The tie as used is shown on this print, and is somewhat different from the Tie Company's standard. The longitudinal I-beams placed under the rail in the joint ties is our own suggestion, and I do not believe has been used elsewhere by them, but I believe it is a good feature.

"This tie has only been used in construction such as is shown on the print, in paved streets, there being about two miles of this construction now under operation. For this class of construction I consider this tie much the best of any that I have ever seen, as the larger proportion of the metal is where it gives the most service.

"The clips holding the tie to the rail I consider a splendid feature, as it tends to strengthen the rail, and each clip serves to a degree as a rail anchor, helping to overcome any creeping of the rail, due to expansion and contraction, and in case of the breaking of the splice bars at a joint, I believe it would hold the rail-ends fairly rigid.

"In further explanation of this construction, I would state that in making the joints, the splice bars and rail-ends were drilled at the mill ⅛-in. smaller in diameter than the bolts and were reamed after the splice bars were in place, to a diameter .008-in. smaller than the diameter of the bolts, which were machine bolts, milled to a true diameter. It took, as a rule, about ten blows with a sledge hammer to drive these bolts home, the bolts being simply scratched slightly, and not scaled.

"The rail ends, before placing, were trued with a steel square and an emory grinder, and the rails brought as tightly together as possible before reaming the splice bars and bolt holes. After the completion of the construction and before any operation, these joints were gone over with an emery wheel, to take away any inequalities in the rails at the joints.

"Although this track was built in extremely hot weather, followed by a winter extremely cold for this section, there was no trouble with any of these joints; in fact, as stated above, even in the extremely cold weather, it was difficult to find the joints.

"I attribute some of the success of this construction to the fact that the numerous tie clips, acting as rail anchors, prevented any undue creeping of the rail during expansion and contraction, thus preventing any excessive strain at any one joint.

"In any future construction, probably the only change I would desire to make would be to increase the height of the rail to 8 in. or 9 in., thus getting a greater height of concrete over the base of the rail and making stiffer rail and making it easier to keep the concrete tight up against the under side of the rail. With the wet mixture which we used in this construction, we found it rather difficult to keep the concrete up against the rail, because of the slight pressure against it. The reinforcement was used simply to strengthen the concrete beam somewhat under the joints and across places where trenches had recently been dug, and was hooked over the adjoining ties simply for convenience in construction.

"We have not as yet used any of these ties in open or ballasted track, but hope to, as we do not see any reason why they should not be as successful there as in concrete construction."

Springfield Traction Company:

This company has constructed at Springfield, Mo., approximately three miles of track made up, as follows: A 7-in., 70-lb. or 80-lb. tee rail section, 62 ft. long, laid on steel ties and directly under each rail, longitudinal concrete beams, each reinforced with two ½-in. twisted steel rods, and a 5-in. concrete cover over the whole structure for a paving foundation.

"All ties were punched for gage of 70-lb. or 80-lb. tee rails; most of the track laid, however, was 70-lb. The ties used were of the I-beam type furnished by the Carnegie Steel Company. The joints in the rails were laid square, that is, opposite to each other, and the joint tie was 6 ft. 8 in. long, top 8½ in., base 4½ in., depth 5 in., weighing 20 lbs. per linear ft. The intermediate ties were of the same length, but weighed 14.5 lbs. per linear ft.; the top was 6 in. wide, the base 4 in. and depth 4¼ in.

"The rails are fastened to the ties with tee bolts with square shoulders and clips, which have square projections on the base which fit into the holes in the ties."

During the year 1911 320 joint ties and 3,520 intermediate ties were used and in 1912 550 joint ties and 3,120 intermediate ties were used. The ties used in 1912 were 4 in. shorter than those used in 1911. In addition to the above, this company has put in 17 sets of steel switch ties and one set of crossover ties. For details of the construction of this track see Fig. 21.

The above information was furnished by Mr. A. C. Polk, formerly Engineer, and Mr. B. J. Daly, Engineer of the Springfield Traction Company.

Twin City Lines:

Mr. Geo. L. Wilson, Engineer Maintenance of Way, says: "Replying to your circular letter of inquiry in regard to metal ties, the Twin City Lines have used no further metal ties since the last report of September 22, 1911. We have no information to report at this time."

Union Traction Company of Indiana:

Mr. Louis A. Mitchell, Superintendent of Roadway, advises as follows: "Replying to your letter of November 4, concerning the use of

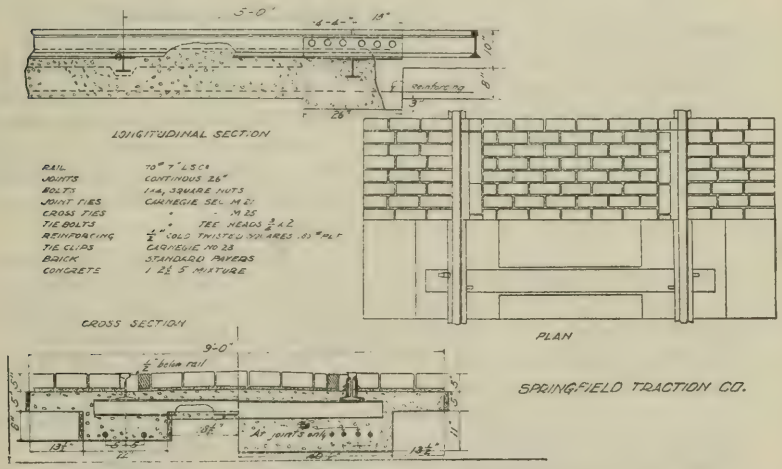

LONGITUDINAL SECTION
RAIL 70# T LSC&
JOINTS CONTINOUS 26"
BOLTS 1/4" SQUARE NUTS
JOINT TIES CARNEGIE SEL. M 21
CROSS TIES " M 25
TIE BOLTS " TEE HEADS 3/4 A.Z.
REINFORCING 1/4" COLD TWISTED SQUARES .65 #PER FT.
TIE CLIPS CARNEGIE NO 23
BRICK STANDARD PAVERS
CONCRETE 1 2½ 5 MIXTURE
CROSS SECTION
PLAN
SPRINGFIELD TRACTION CO.

FIG. NO. 21—CARNEGIE STEEL TIES, SPRINGFIELD, MO.

the International Steel tie for track construction, wish to advise that I have used this tie for the purpose of joint ties, as well as for all of the ties in a track, and I find up to the present time that it is a very efficient device as a substitute for wooden ties.

"Their method of fastening is very much superior to any method which involves a bolt and a nut, as the lugs are held by the wedges, and there is practically no way for the rail to move when these fastenings are placed properly.

"The tie is especially well adapted for a joint tie, as it supports the joint and prevents the slight deflection which occurs in nearly all of the types of rail joints.

"If this type of tie is used entirely in a piece of open track, I believe that the running of the rail would be reduced to a minimum, although I have not used the tie in open track construction, but entirely in street work.

"I am attaching a blueprint which shows the type of construction which I am using, and I hope to be able to use this type of construction for all new track in streets.

"The rail section I have used is Lorain 91-375, and the ties have been spaced 6-ft. centers. The heaviest traffic which we have on a track is a fifty-ton car."

Utica & Mohawk Valley Railway Company:

Mr. M. J. French advises under date of September 28, as follows: "Replying to your inquiry of the 26th inst., I would say that we have used about 1,800 Carnegie M-25 7-ft. steel ties thus far this year with concrete construction in pavement. We find steel tie construction cheaper and we believe it to be more permanent than wooden tie construction for paved streets."

Appendix C.

CONTINUE STUDY OF THE STRESSES TO WHICH CROSS-TIES ARE SUBJECTED, AND DETERMINE SIZE REQUIRED.

This Committee was assigned in 1911-12 the topic "Size of cross-ties required for the stresses to which they are subjected." The report will be found on pp. 301 to 370 and discussion on pp. 951 to 964 of Vol. 13, 1912. The report, with its conclusions, was accepted as information and referred back to the Committee for further investigation and with enlargement of the scope of the topic.

The assigned topic resolves itself into two parts, viz:

(1) Continue the study of the stresses to which cross-ties are subjected; and

(2) Determine the size required.

In order to have an expression of opinion as to the best method for handling the topic, a letter (Exhibit A) was sent to twenty-seven members of the Association, and the replies, fifteen in number, are hereto attached and marked Exhibit B. It will be noted that there is quite a divergence of opinion. "Track Deformation," by Cuenot, to which reference is made later, covers very well many of the suggested methods mentioned in said letters for solving the second half of the topic.

The first part of the assigned topic may be touched upon to the extent of spacing of the ties.

Exhibit F, pp. 312 to 329, Vol. 13, question 1-E, contains answers respecting spacing of ties, a tabulation of which is as follows, to-wit:

The preponderance of the mileage voting is in favor of twelve-inch face to face; the next in favor is ten-inch; the next thirteen-inch. The recommendation of this Committee for 1912 was ten to twelve-inch, and the above table substantiates its recommendation.

The Ballast Committee publishes a translation of "Gravel as Ballast," by C. Bräuning, pp. 267 to 285, Vol. 13. Mr. Bräuning's conclusions, which are in accord with your Committee's recommendations, are as follows:

"Of greater importance than the width of the tie is the spacing of the ties. As the spacing is decreased two advantages are derived; first, the unit pressure is decreased; secondly, the carrying capacity of the roadbed is increased. It is just within the limits of tie spacing usually considered that the relation a-b (a=distance face to face to tie; b=depth of tie) ranging from 3½ to 2 (spacing 35-inch and 19½-inch center to center) that the carrying capacity increases at a high rate. The limiting feature of decreasing tie spacing is the ability to tamp the ties properly. Ties 6½ inches in height can still be tamped with convenience when separated 13½ inches. But this 23-inch from center to center is the lowest limit. This is the one most effective and simplest means of

increasing the strength of the roadbed and to utilize it to the fullest advantage, especially on roadbeds which are fully loaded, is urgently recommended."

Mr. Byers, 11-49, Vol. 1, 1911, International Railway Association, says "20-inch center to center of ties small as practicable." With an 8-inch tie the spacing face to face is 12 inches.

Therefore, your Committee feels that its conclusions are fully in line with Mr. Bräuning's recommendations, though prepared without knowledge of either Messrs. Bräuning's or Byers' conclusions.

TABLE I.

Spacing Face to Face	Name of Company Recommending	Mileage of each Railroad	Mileage for each Spacing	Percentage
6″	American Creosoting Company			
7″	N. Y. C.—G. W. Kittredge		2,829	5%
8″	C. & E. I.		966	2%
10″	B. & A.	628		
10″	G. T.—Burton & Allrug	4,757		
10″	I. C.	2,245		
10″	K. & M.	175		
10″	N. & W. (G. W. Merrell—See 11″)	1,951		
10″	P. & R. (F. S. Stevens—See 13″)	1,509		
10″	P. & L. E. (J. A. Atwood—See 12″)	215	11,480	20%
11″	E. P. & S. W.	902		
11″	N. & W. (C. S. Churchill—See 10″)	1,951		
11″	Q. M. & S.	192	3,045	5%
12″	C. B. & Q.	8,966		
12″	A. T. & S. F.	10,208		
12″	C. R. I. & P. (J. M. Brown—See 13″)	8,020		
12″	P. & L. E. (E. F. Wendt—See 10″)	215		
12″	W. P. T.	64	27,473	47%
13″	C. R. I. & P. (Garrett Davis—See 12″)	8,020		
13″	P. & R. (R. B. Abbott—See 10″)	1,509	9,529	16%
13½″	L. V. (as a maximum)		1,432	2%
15″	W. M.		543	1%
10″ to 12″	L. S. & M. S.		1,663	2%
			58,960	100%
	Total mileage of Association		261,000	
	Percentage here represented, 23%.			

Vol. 13, pp. 306 and 307, gives a table of different number of ties per 30-ft. rail, the percentage of roads using 6x8x8 and table giving the different sizes of cross-ties in current use. The divergence of practice is undoubtedly largely due to varying conditions in different localities and to a tendency to "follow the leader." The latter is probably nearer the mark, as the tendency in American railroading has been in the past, and only now is being broken away from, for the railroad heads always to compare the engineering department recommendations with practice on other roads, with the result that in many lines our progress has been slow.

Your Committee has consulted and read treatises bearing on our topic as follows:

(1) The Track Superstructure of German Railroads, by M. Blum, published by the American Railway Engineering Association, Vol. 11, part 2, pp. 1,338 to 1,378.

(2) Gravel as Ballast, by C. Bräuning, Vol. 13, pp. 267 to 285.

(3 Track Deformation, by G. Cuenot. Translated by W. C. Cushing and published by McGraw-Hill Publishing Company.

(4) Proceedings International Railway Association, Vol. 1, 1911, and Bulletin 5, May, 1910.

(5) Wellington.

Zimmerman's (a German) Treatise on Track, to which reference is often made by Cuenot and "reporters" in the 1910 Proceedings of International Railway Association, is considered by Mr. Cushing good, but your Committee has not been able to secure a copy.

The size of tie is discussed in all six publications, and with much similarity. Mr. Blum states that "on important lines only the maximum dimensions (8x10 1-4x10 1-4x6 5-16 in.) are generally used." In the same article, pp. 1,377 and 1,378, appears a table of dimensions, weights and cost of different systems of track superstructure, both for wooden and metallic ties. Under the former, col. 7, is given size of wood cross-ties on twelve different German roads. The majority uses size above given, viz.: 8x10½x10 1-4x5-16 in.

Mr. Bräuning, Vol. 13, p. 284, recommends "ties 2.8 M. (9 ft. 2.2 in.) in length."

A. M. Wellington, in his treatise on "The Economic Theory of Railway Location," touches admirably on the topic of this Committee in paragraphs 1,044 to 1,050, inclusive. The extracts from these paragraphs as follows are most apropos:

1044. "The number of these (ties) cannot be too great for economy, until they become so close as to impede tamping, which is when about 40 per cent. of the length of the rail rests upon ties.

1046. [illegible] "In endeavoring to get the utmost stability at the least cost, the first essential is to use ties as freely as is possible, and the next essential is to decide between a heavier rail and more tamping to supply the deficit.

1051. [illegible] "The best dimensions for a tie are about 7 in. thick, 8 ft. 6 in. long, and 7 in. to 9 in. face."

Track Deformations by Cuenot is one of the best books on that subject. The book is not based on theory, but entirely "on the experimental method supplemented by explanation derived by calculation from experimental data." This is contrary to the method of the Germans, who have started "from hypotheses not verified by experiment, and have deduced facts from them by calculation which they have taken as established without discussion."

M. Cuenot's experiments were made with

(1) Creosoted oak tie 8 ft. 6.36 in. long x 8.66 to 9.84 wide x 5.51 to 5.91 deep.

(2) Rails 78.62 and 69.5 lbs. per yard, and engine axle loads 24,000 lbs.; total weight of engine and tender 60 tons.

(3) Composite cross-tie system of Devaux, Michel & Richard which "is composed of a metallic skeleton in the form of an inverted trough provided in the interior with two symmetrical blocks of wood solidly fixed and leaving between them an empty central space." See pp. 2 and 3, Track Deformation, for detailed plan.

On p. 58 of Cuenot it is stated that "the following points should be retained from the study which has been made":

(a) "The long ties 8 ft. 6.36 in. to 7 ft. 6.6 in. take, under the load, the form of a basin with the bottom slightly raised in the center.

(b) "The short ties 7 ft. 6.6 in. to 6.5 ft. are deformed according to a curve, convex or otherwise, and inclined toward the extremity.

(c) "The ties between 7 ft. 0.6 in. and 7 ft. 2.64 in. are lowered parallel with themselves without sensible curvature.

d) "The unsymmetrical tamping raises the curve towards the center; a very feeble lack of symmetry reacts very clearly in this direction.

(e) "It is possible, then, by increasing the rigidity of a cross-tie, notably by concentrating the material about the supports, to reduce its sinking to the quantity which is intended as a limit, and its flexure in such a measure as one would wish.

(f) "The permanent sinking of the ballast is variable according to the case, but the elastic sinking, the only one there is reason to consider, is, so to speak, constant whatever the length and type of the cross-tie adopted. The deformation is slowly produced and augments with time." (With 24-in. crushed rock superimposed on "a layer of engine cinders, gravel, or equivalent, to act as an absorbent mat" (see Vol. 13, p. 127) such a condition may be obtained. Committee.)

The reference is that a short, thick tie is preferable. Mr. Cushing states in a letter of May 2, 1912, to the Chairman, "The latter (Cuenot) is an advocate of short ties, but you will find the Germans and Englishmen in favor of long ties." The German gage is 4 ft. 9 3-32 in., as shown in sketch on p. 3 of Cuenot.

J. W. Jacomb-Hood, question 2, p. 12, Vol. 1, 1910, International Railway Association, states that for gage of 4 ft, 8½ in. a minimum of 9 ft. should be adopted for length of tie. Pp. 13, 14 and 15 might be quoted in full, but in order to avoid too large a report it is left to the reader to secure that volume if so inclined. The pages in question are practically a discussion of Track Deformation by Cuenot.

The question of length of ties in various European countries, as given in table 4, pp. 510, 511, Vol. 1, 1910 International Railway Association, varies but a few inches from 8 ft. 6 in. The P. L. & M. (M. Cuenot's road) is there given as 8 ft. 6.3 in., though M. Cuenot's recom-

mendations are for a shorter tie, the exact length of which is not stated in his book.

Mr. Rosche (German), discussing strengthening of the track, II-647, 1911 Proceedings International Railway Association, states:

"Both in theory and in practice the best sleepers, from the point of view of stability in track, are 8 ft. 10 5-16 in., with a seat of 10¼ in."

Table 4, II-510 and 511, gives German roads as about 8 ft. 6 in.

Zimmerman is quoted as saying, 8 ft. 2 7-16 in.

Mr. Blum, II-654, states 8 ft. 6 3-8 to 8 ft. 10 5-16 in. in length, and on same page states:

"The length of the sleepers is a very great factor in the strength of track. This has been proven, especially by Zimmerman's investigations; and practice has shown that it is not advisable to have a length less than 5.50 metres (8 ft. 2 7-16 in.), that is rather a low figure, and length of 2.6 to 2.7 metres (8 ft. 6 3-8 to 8 ft. 10 5-16 in.) is to be preferred. The smoothness of running on English roadways is, in my opinion, chiefly due to the fact that sleepers are 8 ft. 11 in. in length and upwards and have been in use there for a long time."

Mr. Jacomb-Hood, on II-657 states:

"Cross-ties. The experiments of Mr. Cuenot point to an advantage in reducing the length of timber cross-ties, while an increased depth would allow a stronger fastening. Future improvements will probably be found in a material which is less elastic and more rigid. The difficulty of keeping the fastenings tight is the chief objection to a steel sleeper. Reinforced concrete sleepers are in too early a stage of development for an opinion to be expressed upon them. But some form of steel with timber blocks to form a bearing for the rail or chair should have as long a life as any other form, and should be no more costly."

Mr. Cuenot, p. 146, concludes his treatise as follows:

"We conclude, then, that, in order to have tracks in a condition for supporting a heavy and rapid traffic, there are necessary:

"1. Cross-ties extremely rigid, two to three times more so than those actually in use, which excludes in every case the employment of cross-ties exclusively of steel in the form of a trough.

"2. The laying of the track with a cross-tie under the joint, that cross-tie being followed and preceded at 11.81 in. with cross-ties equally rigid.

"3. The use of reinforced plates (tie-plates)."

Herman Rosche, Bulletin 5, May, 1910, International Railway Association, submits Report 8 (pp. 1,895 to 1,966, inc.). "On the question of strengthening the track with a view to increasing the weight of locomotives and the speed of trains" based on information secured from Austria, Hungary, Bulgaria, Rumania, Servia and Turkey, from which report the following extracts are made, viz:

P. 1,901. "Class of locomotives and rolling stock. The design of the locomotives has been strongly influenced and limited by the older regula-

tions of the German Verein on the magnitude of the admissible wheel loads.

"The maximum axle loads of the Austrian locomotives are at present 14 to 14.6 tons (13.8 to 14.4 English tons), and those of the Hungarian locomotives, 15.9 tons (15.6 English tons). Diagrams showing the wheel loads of these locomotives are given in appendices 5 to 7.

"In appendix 8, we show for purposes of comparison a large number of locomotives of more recent construction in other countries. These show that the greatest axle loads considered admissible are: Germany, 17.7 tons; France, 18 tons; Belgian States Railways, 19 tons; England, 20.8 tons; America, 24.4 tons."

Pp. 1,910–1,912. "The increase in the weight of locomotives is an immediate consequence of the continual increase in the demands made on the power of locomotives. Not only is it necessary to haul as large train loads as possible, also on mountain lines where there are unfavorable conditions, gradients and curves, but there is also a demand for increasing the speed of passenger trains, which are at the same time continually becoming heavier; this necessitated an increased adhesive weight and a larger boiler and firebox, and so led to locomotives being made larger and larger. The locomotive engineer had thus to deal with problems which he had to solve, while he had at the same time not to exceed certain limits as regards the track and the bridges and the economy of working.

"A comparison of Stephenson's first locomotive, the Rocket, built in 1829, and weighing in working order 4.5 tons, and its tender of 3 tons, with the new American locomotive weighing in working order 100 tons and having wheel loads of over 12 tons, shows how great the increase in the weight of locomotives between the time when railways first started and the present day has been.

"At the same time, the speed at which these locomotives have to run has increased from 24 kilometres (15 miles) per hour to 150 kilometres (93 miles) per hour; and while, about ten years ago, average speeds of 85 kilometres (52.8 miles) per hour were considered as the maximum, these have since increased to 100 kilometres (62 miles) per hour, while the train loads have increased to 400 tons, and non-stop runs of up to 300 kilometres (186 miles) are made.

"In Austra-Hungary and Germany, after 1850, this development under the influence of the engineers of the Verein, was not so rapid as in other countries, but, on the other hand, more attention was paid to the track.

"On the first locomotive railway built in Austria, the Kaiser Ferdinand's Nordbahn, the locomotives used in 1837 had a weight in running order of 14.6 tons (14.4 English tons) and a maximum wheel load of 3 tons (2.95 English tons); a chair superstructure with iron rails weighing 19 kilograms per metre (38.30 lb. per yard) and having a moment of resistance of 35.5 cubic centimetres (2.17 cubic inches) sufficed for the purpose. But in 1844, the weight of the locomotives was increased to

24.6 tons (24.2 English tons) and the wheel load to 6 tons (5.9 English tons); and this increase in the wheel load led to the introduction of rails having a weight of 37 kilograms per metre (74.59 lbs. per yard) with a moment of resistance of 105.5 cubic centimetres (6.44 cubic inches). These rails were supported on sleepers spaced 95 centimetres (3 ft. 1 3-8 in.) apart. Thus an increase in the wheel load of 100 per cent. was met by an increase of 200 per cent. in the stiffness of the rails.

"The wheel load of 6 tons (5.9 English tons), as a result of the practice on German railways, became recognized in 1850 in the whole of central Europe, as the maximum load the rails had to bear. In 1858, the maximum admissible wheel load was increased to 6.5 tons (6.4 English tons) and in 1871 to 7 tons (6.9 English tons). The weight of the locomotives, in working order, increased up to 50 tons (49.2 English tons). Permanent way engineers could at that time provide a correspondingly strong track without increasing the weight of the rails, as in the meantime rails of considerably greater strength could be obtained by using steel instead of iron, in fact it was even possible to use rails which were lighter than the iron rails previously used. At that time, it was considered that it was sufficient if the track was laid with steel rails weighing 31 to 35 kilograms per metre (62.50 to 70.55 lb. per yard), having a moment of resistance of 120 to 150 cubic centimetres (7.32 to 9.15 cubic inches) supported on sleepers 2.4 metres (7 ft. 10½ in.) long and having a moment of resistance of about 910 cubic centimetres (55.5 cubic inches), the sleepers being spaced up to 100 centimetres (3 ft. 3 3-8 in.) apart. In 1893 the technical meeting of the Verein decided that it was advisable to strengthen this superstructure, in the first place for economical reasons.

"The growing demand on the power of locomotives resulting from the wish to increase speeds, then led Austria-Hungary and the German Verein to raise the admissible wheel load still further, and accordingly the new technical regulations of the German Verein, of 1908, specify that the rails of the tracks on which locomotives run must be able to carry with safety, even at the highest speeds, vehicles having wheel loads of 7 tons (6.9 English tons), and not later than Jan. 1, 1920, also of 7.5 tons (7.4 English tons), such loads being determined with the vehicles at rest. It is at the same time advised that the wheels of the steam locomotives should be of such a diameter that a given number of revolutions per minute (determined for each type of locomotive) must not be exceeded, and subject to the condition that the centrifugal force acting on each wheel at the maximum authorized speed does not exceed 15 per cent. of the wheel load, the latter being determined in a state of rest. As regards new tracks, it is specified that the rails must have such strength that they are able to carry with safety, even at the highest speed, wheel loads of 8 tons (7.9 English tons). The wheel load of vehicles, which are not prohibited from going on other lines, may it is true as a rule not exceed 7 tons (6.9 English tons) (determined at rest), yet with locomotives of certain designs and at speeds up to 50

kilometres (31 miles) per hour a wheel load of 7.5 tons (7.4 English tons) is considered admissible; and on their own individual railways, the wheel load can be still further increased, regard being paid to the order of the wheels within the limits of the strength of the track and the bridges.

"Actually the working regulations for the main railways in Germany provide for a wheel load of 9 tons (8.9 English tons); and on the express lines of Austria and Hungary, as already stated in the first part of this report, there are locomotives weighing in working order up to 77.3 tons (76 English tons), with an adhesive weight of up to 68.5 tons (67.4 English tons) and an axle load of up to 15.9 tons (15.6 English tons) in use, while on the express lines of other countries there are locomotives weighing in working order up to 100 tons (98.4 English tons), with an adhesive weight of up to 60 tons (59 English tons) and an axle load of up to 24 tons (23.6 English tons). The trains hauled by these locomotives weigh up to 400 tons (394 English tons) and the maximum speed has already been increased in other countries to 150 kilometres (93 miles) per hour, as already stated, while in Austria and Hungary, it only amounts to 90 kilometres (56 miles) per hour."

Pp. 1,914-1,915. "This superstructure theory together with a number of mathematical investigations of existing superstructures, made with its help more especially by Ast and Blum, have enabled us to obtain certain information of which the following is a summary:

"1. The recognition of the influence which, besides that exercised by the rails, is exercised by the rail supports and the ballast on the carrying power and on the stiffness of the track. This has shown that it is not possible to strengthen the superstructure effectively by improving individual members, more especially by merely increasing the weight and the moment of resistance of the rails, but that it is only possible to effect this by a uniform distribution of the resistance on all the members of the track, and by strengthening them to a corresponding extent.

"2. As regards ballast, it seems established that the pressure on the ballast becomes distributed over a surface of formation level which is greater, the greater the depth of the ballast, and that by increasing the coefficient of ballast, that is to say, the resistance of the ballast, the depression of the track is reduced, and consequently the stiffness of the track increased, in a very effective manner.

"3. As regards sleepers, it is established that the length of the sleepers has more especially a material influence on the rigidity of the whole track. The sleeper is the more unsteady, the greater the differences in the pressure on the ballast and in the depression of the sleepers at different points. Calculations show that the least differences between the middle and the end of the sleepers occur when the sleepers are about 2.7 metres (8 ft. 10 5-16 in.) long, while with very short sleepers the depression of the ends of the sleepers is greater than at the points supporting the rails; that moreover when the width of the sleepers is increased, the pressure on the ballast, the depression of the sleepers and

the bending moments of the rails are reduced, and that the way in which the sleeper is packed also influences its depression and fatigue.

"4. As regards rails, it is established that the amount they bend varies directly as the cube of the distance between the points of support and inversely as the moment of inertia of the rail. As moreover the depression of the rail becomes less when the coefficient of ballast and the area of sleeper seat are increased, it follows that the dimensions of the sleeper seat and the spacing of the sleepers, as well as the depth of the ballast and its quality, exercise a material influence on the carrying power and stiffness of the rails."

P. 1,922. "The table (appendix 17) shows also the great influence of the dimensions of the sleepers on the stresses produced in the rails and ballast, and on the stiffness of the track.

"Thus superstructures Nos. 6 and 8 are nearly the same as far as rails are concerned; yet in spite of the greater distance between sleepers in No. 8, the stresses acting on the rails are 6 per cent. and on the ballast 8 per cent. less and the depressions are 5 per cent. less, than in the case of superstructure No. 6, because the sleepers 2.5 metres (8 ft. 2 7-16 in.) long are replaced by sleepers 2.7 metres (8 ft. 10 5-16 in.) long and 26 centimetres (10 1-4 in.) wide at the bottom.

"A comparison of the depressions of sleepers of different length shows the influence the longer sleeper has on the stiffness of the track and consequently on the reduction of the dynamic actions.

"While in the case of No. 11, sleepers 2.4 metres (7 ft. 10½ in.) long, the difference between the depressions of the sleepers at the points above which the loads are applied and the depressions at the middle of the sleeper amounts to 0.9 millimetre (3-64 in.) it is only 0.5 to 0.6 millimetre (1-64 to 1-32 in.) in the case of the sleepers 2.7 metres (8 ft. 10 5-16 in.) long; i. e., about 40 per cent. less.

"The superiority of the long stiff sleeper, however, becomes more apparent, the less good the ballast is (or becomes, in consequence of the traffic), as in the case of short sleepers the difference between the depressions at the loading point and at the middle of the sleeper become greater, the smaller the coefficient of the ballast."

Pp. 1,927-8-9. "Sleepers. We have already considered the importance of the sleeper and its dimensions from the point of view of the stiffness of the track, and found that both theory and practice are in favor of sleepers 2.7 metres (8 ft. 10 5-16 in.) long, 26 centimetres (10 1-4 in.) wide at the bottom and having a moment of resistance of about 900 cubic centimetres (54.92 cubic in.). Sleepers of these dimensions are in use on German, Austrian, Hungarian and English railways, and give good results.

"It is true that recently Cuenot and after him Schlussel have spoken in favor of stiff sleepers only 2.2 metres (7 ft. 2 5-8 in.) in length, which together with supported rail joints are to give the track a greater stiffness than is obtainable with longer flexible sleepers.

"But the theoretical and practical determinations concerning the bending and the depression of sleepers of different lengths, described above, show that short sleepers have a much more unfavorable influence on the track.

"Cuenot's determinations are based on too small a number of observations, and do not agree sufficiently well between themselves to allow reliable conclusions to be drawn. These would also have become different if the 2.2 metre (7 ft. 2 5-8 in.) long sleeper had been compared with an iron sleeper 2.7 metres (8 ft. 10 5-16 in.) long with a corresponding moment of resistance. It has, however, to be admitted that the superiority of long sleepers over short sleepers becomes less when the coefficient of ballast increases.

"The strength of the sleeper depends not only on its dimensions, but also on its material. The wooden sleeper, which makes a proper transmission of the rail pressure to the ballast possible, still continues to hold the premier position among transverse sleepers. Its chief defects are its comparatively small resistance to external forces, particularly at the points where the fastenings are, and its liability to decay.

"The first defect has become of little importance, now that hard wood tree-nails are used with the soft wood sleepers, and that the rails are supported on bedplates and chairs having a large base, so that the fastenings of the rail and the bedplate are separate.

"The second defect has been ameliorated by pickling the sleepers with antiseptic liquids.

"The shortage in wood supplies and the desire for a permanently better fastening of the rail to the sleeper induced Germany and Austria, in the middle of last century, to use iron sleepers. At first the iron sleepers were made too short, too light, and with too small a moment of resistance; this contributed largely to an unfavorable opinion of iron sleepers. The inferiority of the iron sleepers lately examined by Cuenot is also the consequence of their dimensions being too small. Actually, however, several forms of iron transverse sleepers have been worked out during the last few decades, which are equal to, or even better than, wooden transverse sleepers, both as regards the possibility of obtaining a good track and efficient fastenings, and as regards cost of maintenance. That they are of equal value statistically, has been shown by Ast, Kowalski, Blum and others. The choice between wooden sleepers and iron sleepers is therefore entirely dependent on economical considerations; it will vary in each country according to the supplies available.

"The compound sleepers lately recommended by Cuenot and Schlussel (iron sleepers with wooden blocks which are to give the sleeper a greater bearing surface under the rail) have this objection, that with the construction proposed, it is not to be expected that the wood and iron will hold together and work together permanently. The trials of reinforced concrete sleepers, which began in America in 1899, have of late been much extended. The object aimed at is to increase the stability of the track by the increased stiffness of these reinforced concrete sleepers and

by their increased weight (about 2 or 3 times as great); and the manufacturers think that reinforced concrete sleepers will also prove economically superior to sleepers made of other materials.

"According to Bastian, trials have been made, not only in America, but also on Bavarian and Italian railways, with a large number of reinforced concrete sleepers of different designs, and we are also informed that the Austrian State Railway has quite recently initiated such trials. It is self-evident that no opinion can as yet be formed on the subject, as experience is too short; in many cases, however, bad results were obtained in a comparatively short time. The difficulty is to design a permanently reliable fastening for securing the rail to the reinforced concrete sleeper. Wood or iron plates are generally interposed, and it is to be feared that there will be greater wear at the fastenings.

"Schaub has also proposed for the extensions of the New York Subway, that the track should be wholly embedded in reinforced concrete.

"Experience alone could show whether such a track, which would be very inaccessible as regards adjustment, could resist the impact effect produced by the vehicles for any length of time; at present this must be considered doubtful.

"Our calculations, appendix 18, shows that the use of wooden transverse sleepers, 2.7 metres (8 ft. 10 5-16 in.) long, of proper cross-section, will still give satisfactory results with higher wheel loads than at present used.

"The comparatively large stresses, which act on wooden sleepers of the cross-section assumed in our calculations, such as used on Austrian and German railways, if there are wheel loads of 11 and 12 tons (10.8 and 11.8 English tons), can be avoided by using sleepers having the American cross-section, with a depth of 18 centimetres (7 inches); this also speaks in favor of using iron or reinforced concrete sleepers.

"It is true that the stresses acting on the rails, in a wooden transverse sleeper superstructure, if calculated taking into consideration the compressibility of the wood of the sleepers, are appreciably higher, but the stresses on the sleepers and the pressure on the ballast become consequently reduced at the same time; in other words, the admissible limit of the stress on the ballast is only reached with greater wheel loads than assumed in the calculations; and in this way, the wooden sleeper is superior to the iron or reinforced concrete sleeper.

"The stresses on the sleepers, the pressure on the ballast and the depression of the sleepers can also be reduced by about 20 per cent. by placing the sleepers closer together, reducing the distance of 80 to 60 centimetres (2 ft. 7½ in. to 1 ft. 11 5-8 in.); this will reduce the stresses on the rails, even with wheel loads of 12 tons (11.8 English tons), to such an extent that they will be less than one-third of the limit of elasticity."

Pp. 1,934-1,935. "The track as a whole. We have investigated the question, to what extent the component members of a superstructure which has been found satisfactory for speeds of 120 kilometres (74.5

miles) per hour and wheel loads of 8 tons (7.9 English tons), can be and must be strengthened, if the wheel loads are to be increased still further. This examination has shown, that the first condition for any greater fatigue of the track is a stronger roadbed, and that the track can accordingly be improved most effectively by having a deep layer of ballast, consisting of hard broken stone.

"This strengthening of the roadbed and improvement of the ballasting accordingly forms the condition sine qua non for any further increase in wheel loads and train speeds.

"In addition to the ballasting, another efficient means for reducing the pressure on the ballast and the stresses on the rails, and for giving at the same time the track the greater resistance to lateral and longitudinal forces it requires at higher speeds, consists in placing the sleepers closer together so that they are about 60 centimetres (1 ft. 1 5-8 in.) apart. On American railways, the use of iron packing bars has made it possible to have the sleepers even closer. If sleepers 2.7 metres (8 ft. 10 5-16 in.) long and 26 centimetres (10 1-4 in.) wide at the bottom are used the supporting surface per metre of track is increased from 0.9 to 1.19 square meters (8.86 to 11.71 square feet), that is, by 30 per cent.

"It is true that the rails can be made still heavier, but it would be more effective to improve the quality of the metal than to alter the cross-section, and consequently the possibility of allowing greater stresses to act on the rail will also depend on any success attained in this direction.

"In considering the strengthened superstructure, we have therefore only assumed a rail having a moment of inertia of 1,500 square centimetres squared (36.04 square inches squared) and a moment of resistance of 210 cubic centimetres (12.82 cubic inches), that is, a rail weighing about 45 kilograms per metre (90.71 lb. per yard).

"Our calculations show that each additional ton of wheel load increases the stresses acting on the rails by 91 to 112 kilograms per square centimetre (1,294 to 1,593 lb. per square inch), the stresses acting on the sleepers by 6.3 to 8.6 kilograms per square centimetre (89.60 to 122.32 lb. per square inch), the pressure acting on the ballast by 0.14 to 0.22 kilogram per square centimetre (2 to 3.13 lb. per square inch), and the depression of the sleepers at the points at which they are loaded by 0.12 to 0.22 millimetre (0.005 to 0.009 inch). At the same time, our calculations show that wheel loads of up to 12 tons (11.18 English tons) would not produce any inadmissible stresses acting on the rails and sleepers; for if the coefficient of ballast C—8 and the sleepers are spaced at 70 centimetres (2 ft. 3 9-16 in.), the stresses acting on the rails are 1,300 kilograms per square centimetre (18,490 lb. per square inch), and on the sleepers, 84 kilograms per square centimetre (1,195 lb. per square inch), that is to say, they do not yet attain one-third of the elastic limit and the road could bear three times the static load.

"It is true that the pressure on the ballast would then amount to 2.0 kilograms per square centimetre (28.45 lb. per square inch); and the

maximum depressions of the sleepers are calculated to amount to 2.4 millimetres (3-32 inch).

"By reducing the spacing of the sleepers to 60 centimetres (1 ft. 11 5-8 in.) the pressure acting on the ballast can be reduced to 1.7 kilograms per square centimetre (24.18 lb. per square inch), and the depression of the sleepers to 2.16 millimetres (0.085 inch). If it is possible to have ballasting with C—15, such a superstructure would then only show depressions of 1.43 millimetre (0.056 inch), a figure which would make it admissible in the case of the ballast also to have a doubling of the static load by the dynamic actions."

P. 1,936. "Conclusion. The transverse sleeper superstructure at present usual on express lines can be made and kept sufficiently strong for heavier wheel loads and higher speeds than now generally customary in railway working, by placing a sufficiently deep layer of ballast, consisting of hard broken stone, on a firm roadbed, by using rails weighing up to 50 kilograms per metre (100.80 lb. per yard), made of hard tough steel of uniform quality, laid on stiff transverse sleepers made of wood, iron or reinforced concrete, and placed 60 centimetres (1 ft. 11 5-8 in.) apart, provided that care be taken that such tracks are run over by express trains, with locomotives and carriages designed to produce as little dynamic action as possible.

"It is, however, in the first place desirable to determine the suitability of such tracks for speeds of over 150 kilometres (93 miles) per hour by tests of the dynamic actions produced at such speeds by the locomotives and the carriages and of the lateral forces acting on the track."

The determination of size of cross-tie has been thoroughly covered by the foregoing, but no definite conclusions should or can be drawn from neither Cuenot's nor Rosche's experiments. Cuenot based his experiments (1) on oak ties alone and they were performed in a few places only which would not make them applicable to all ties, all places and all conditions; (2) on medium light rail and with extremely light axle loads both for engines and cars. Rosche's experiments were likewise based on light axle loads as compared with American practice. Therefore, in considering European practice and deductions from experiments, Americans must consider the limitations and make allowances accordingly, i. e., consider them as guides only. When European conclusions as to tie spacing face to face, 13 inches to 14 inches, are applied in this country, the spacing must be decreased to allow for such varying conditions. Hence the Committee's recommendation last year of 10 inches to 12 inches face to face would appear good practice. If the same deductions were followed as to length, the major length now so popular in America would really be increased to 8 feet 10 inches if not 9 feet 0 inch. Therefore, it may seem that a tie 7x9x8 feet 6 inches already adopted by a large number of American roads, as shown in Exhibit D, p. 307, Vol. 13, 1912, should be adopted as standard, as it fulfills all requirements heretofore brought out. But the majority of

roads as per said Exhibit D use a tie 6x8x8 and it is doubtful whether or not such roads will consider a larger tie, especially so since tie timber is becoming scare in this country.

The International Railway Congress Association, Bulletin 10, October, 1912, has assigned through its Permanent Commission for discussion at the 1915 session of the Congress, a list of questions, among which under Way and Works are the following, viz.:

I. Construction of the Roadbed and of the Track.

Arrangement to be adopted in constructing the roadbed and the track, in view of the increase of the weight of locomotives and the speed of trains.

H. U. MUDGE,
Reporter for America.

II. Maintenance and Supervision of the Track.

Measures to be taken to provide an economic organization for the maintenance and supervision of the track, taking into consideration the increase of traffic and speed as well as the rise in wages and in the cost of materials. Use of mechanical appliances. Results obtained.

EPES RANDOLPH,
Reporter for America.

III. Special Steels.

Use of a special steel both for the track generally, and in particular for the track appliances (points, crossings, etc.).

W. C. CUSHING,
Reporter for America.

IV. Reinforced Concrete.

Use of ordinary concrete and of reinforced concrete on railways.

C. H. CARTLIDGE,
Reporter for America.

The four reports under Way and Works will have much valuable information bearing on the topic assigned to this sub-committee.

We submit the foregoing as the progress of this Committee for this year; it contains much information for the benefit of the members of the Association and we will continue the study for next year. It is thought by the Committee that we should conduct some physical investigations and that funds should be provided for that purpose. This will be referred to the Board of Direction.

EXHIBIT A.

*1. E. F. Wendt, Assistant Engineer, Pittsburgh & Lake Erie Railroad, Pittsburgh, Pa.

2. Wm. Hood, Chief Engineer, Southern Pacific Railway, San Francisco, Cal.

*3. R. L. Huntley, Chief Engineer, Union Pacific Railroad, Omaha, Neb.

*Those replying.

4. W. L. Darling, Chief Engineer, Northern Pacific Railway, St. Paul, Minn.

5. W. J. Harahan, Vice-President, Erie Railroad, New York, N. Y.

6. A. C. Shand, Chief Engineer, Pennsylvania Railroad, Philadelphia, Pa.

7. G. H. Webb, Chief Engineer, Michigan Central Railroad, Detroit, Mich.

*8. W. J. Wilgus, Consulting Engineer, 165 Broadway, New York, N. Y.

9. J. G. Sullivan, Chief Engineer, Western Lines Canadian Pacific Railway, Winnipeg, Man.

*10. G. C. Cleveland, Chief Engineer, Lake Shore & Michigan Southern Railway, Cleveland, Ohio.

11. G. H. Bremner, Engineer, Illinois District Chicago, Burlington & Quincy Railroad, Chicago, Ill.

12. C. F. Loweth, Chief Engineer, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill.

*13. A. S. Baldwin, Chief Engineer, Illinois Central Railroad, Chicago, Ill.

14. J. A. Atwood, Chief Engineer, Pittsburgh & Lake Erie Railroad, Pittsburgh, Pa.

*15. Robert Trimble, Chief Engineer Maintenance of Way, Northwest System, Pennsylvania Lines West of Pittsburgh, Pittsburgh, Pa.

*16. F. S. Stevens, Engineer Maintenance of Way, Philadelphia & Reading Railway, Reading, Pa.

17. J. B. Berry, Chief Engineer, Chicago, Rock Island & Pacific Railroad, Chicago, Ill.

*18. A. W. Thompson, Third Vice-President, Baltimore & Ohio Railroad, Baltimore, Md.

*19. W. B. Storey, Jr., Vice-President, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

*20. A. H. Rudd, Signal Engineer, Pennsylvania Railroad, Philadelphia, Pa.

*21. L. C. Fritch, Chief Engineer, Chicago Great Western Railroad, Chicago, Ill.

22. Wm. McNab, Principal Assistant Engineer, Grand Trunk Railway System, Montreal, Canada.

23. A. W. Johnston, General Manager, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

24. H. G. Kelley, Vice-President, Grand Trunk Railway, Montreal, Canada.

*25. Hunter McDonald, Chief Engineer, Nashville, Chattanooga & St. Louis Railway, Nashville, Tenn.

*26. C. S. Churchill, Chief Engineer, Norfolk & Western Railroad, Roanoke, Va.

*27. C. F. Ford, Supervisor, Tie and Timber Department, Rock Island Lines, Chicago, Ill.

*Those replying.

Dear Sir:—The American Railway Engineer Association Committee on Outline of Work has assigned as one topic to the Tie Committee the following: "Continue study of the stresses to which cross-ties are subjected and determine size required," and it has been turned over to Sub-Committee B for action.

As this problem has many factors entering into it, and as these factors necessarily change in different parts of the country and on different roads, I shall be very glad if you will give me your views on the following: first, however, reading the report of Sub-Committee A of the Tie Committee, Bulletin 142, pp. 301-331:

(1) Along what line do you recommend the continuance of the "study of stresses to which cross-ties are subjected?"

(2) How would you "determine size required" for cross-ties, and is such determination capable of rational solution?

H. S. WILGUS,
Chairman Sub-Committee "B," Tie Committee.

EXHIBIT B.

Edwin F. Wendt, The Pittsburgh & Lake Erie Railroad Co.:

"Answering your inquiry of May 28—File S-55—respecting committee work of American Railway Engineering Association, especially with reference to the study of stresses to which cross-ties are subjected, I beg to state that Mr. W. C. Cushing, Chief Engineer Pennsylvania Lines West of Pittsburgh has given this subject considerable study, and the question was assigned to your Committee at his suggestion. I feel confident that he is in a position to furnish some valuable data, and would suggest that you write him."

R. L. Huntley, Union Pacific Railroad Company:

"Referring to your communication of May 28 in regard to study of stresses in cross-ties:

"Would advise that we have not conducted any experiments or made any study along the lines suggested by your question, as per Bulletin 142, pp. 301 to 331. Will therefore hardly be able to give you any information in regard to the above which would be of value.

"Regretting my not being able to furnish you any valuable information in regard to this."

From William J. Wilgus:

"Replying to your letter of May 28 (File S-55), I am of the opinion that a study of the stresses to which cross-ties are subjected will yield purely academic results, and that the size of the ties should be determined by general experience.

"The conditions surrounding the use of cross-ties are various and uncertain and, as in the case of retaining walls, it would seem as if any assumption that may be made for a rational solution may be entirely different from many conditions of actual usage involving, as they do, weights of motive power, character of ballast, weight of rail, subdrainage, roadbed, materials, weather conditions, nature of tie, speed of trains, etc.

"Summarizing, in my judgment the proper size of ties should be determined empirically, based on the wide experience of American engineers."

G. C. Cleveland, New York Central Lines:

"Referring to yours of May 28, file S-55, in regard to work assigned to Sub-Committee "B," Tie Committee:

"In regard to question No. 1—The following factors enter into the stresses to which cross-ties are subjected, i. e., the quality of ballast, the size and number of ties per rail length, the weight of the rail, and the speed and tonnage hauled over the track. The question of stresses in ties, I do not think can be discussed intelligently unless these factors are considered. It seems to me that experiments could be made along much the same lines as have been made to ascertain deflection and impact on bridges, and I believe that the relation of the above mentioned factors can be established. There is a limit of economy in thickening up ties in order to support light rail, and generally the greater resistance of heavy rails to deflection will result in less concentration of load on the individual tie, and will, therefore, result in a decrease of the stresses in the individual tie and reduce the number of ties per rail length. If the relations of the factors I have mentioned can be established I think it would be valuable information, as an economic ratio between ties, rails and ballast could then be arrived at, which would probably result in a considerable saving in maintenance and increased efficiency in track. However, it would take quite an amount of experimenting.

"In regard to question No. 2, the size of ties is determined chiefly by the kind of traffic and the relative cost of small ties with larger ties. The question of getting larger ties is limited on account of the supply."

A. S. Baldwin, Illinois Central Railroad Company:

"Referring to your letter of May 28, with reference to information desired by the Sub-Committee on Ties, American Railway Engineering Association:

"I have read report of Sub-Committee 'A' of the Tie Committee, Bulletin 142, pp. 301 to 331, and in reply to your inquiries have to advise as follows:

"No. 1—Along what line do you recommend the continuance of the 'Study of stresses to which cross-ties are subjected?'

"Would recommend that stresses to which cross-ties are subjected be determined for rail of different weights, with maximum axle loads, various speeds, and different tie spacing and ballast.

"No. 2—How would you 'determine size required for cross-ties,' and is such determination capable of rational solution?'

"Size of tie should be determined by crushing strength obtained by continued application of maximum axle loads and for different speeds, and is, therefore, largely empirical."

F. S. Stevens, Philadelphia & Reading Railway:

"Referring to your letter of May 28, file S-55, in relation to the work of your Committee:

"I beg to suggest that perhaps some benefit can be obtained by a study of the question of improved support by using concrete or other material as a foundation, and tamp or readjust it only at long intervals if at all, the direct support of the rails being of wood or other reasonably non-conductive material so that the track circuit can be used without large increase in cost on account of insulation.

"The cost of tamping and retamping cross-ties is a large item in our maintenance charges, and this cost increases rapidly when renewals of ties make frequent retamping necessary, whereas if the tie or foundation can be made of concrete and the immediate support of the rail can be made wedge shaped and adjustable and independent of the tie or principal support, but still a part of it, it is probable, I think, that better line and surface can be maintained and at much less cost than by present methods.

"Some of the trouble we now have is caused by spikes being driven too far down so that the heads bear hard against the bases of the rails until the base of the rail cuts into them. When the ties and rails are held so firmly together, and the contact is so intimate, the tie must, of course, participate in every movement of the rail, and, therefore, require more frequent tamping than after the rail becomes somewhat loosened in the spikes and the recoil and reaction of the rail under passing loads does not cause violent and repeated pounding of the tie on its bed with the consequent disastrous results, as is the case when the spikes are driven to the limit.

"If a support for our tracks can be provided that will be satisfactory and line and surface can be adjusted in some better and cheaper way than by tamping cross-ties, we should, I think, discover it. My thought is that ties or supports of concrete placed quite close together would make a suitable base, and that if adjustable wedges are fitted to inclined surfaces, such wedges can be pushed outward from the center to compensate for settlement and the alinement can be adjusted through slots in the wooden blocks.

"A form of construction that requires so much adjustment and so much expense for maintenance as our present type of track, cannot be called permanent. We should have something better, but to be better it must, I think, cost more to build and less to maintain.

"In answer to question No. 2, in relation to size of cross-ties, I beg to say that in my opinion the size should be proportional to the service required. If we have a roadbed of rock we do not require ballast to distribute the load, but only as a cushion and means of adjustment, and the size of the tie is comparatively unimportant. If the roadbed is soft or yielding, we use a depth of ballast sufficient to distribute the load as evenly as possible over a wide area and use ties of good size. It appears, therefore, that as conditions vary there can be no fixed rule to govern in the matter of size of ties required, but as roadbeds generally increase in firmness with age, the question of size of ties for use in principal tracks gradually disappears.

"As a general proposition probably all will agree that with our present construction, that size of tie is best that can be most effectively tamped or probably with a width of face of from eight to ten inches, according to the skill and experience of the men employed in this work.

"We all know that the weakest place in our tracks is the rail joint, and that, therefore, the joint is the place that receives most attention and a large share of the cost of maintenance. It appears, therefore, that our greatest need is a joint that is actually as well as nominally 100 per cent. under a static load when in first-class condition, and, of course, very much less under ordinary conditions.

"A practically continuous rail so far as strength is concerned would, of course, eliminate the problem of the low joint, and, therefore, also to a great extent the troubles due to creeping track, for unless there is wave motion rails will not creep, and if the surface is good and the ties are evenly tamped, and the superelevation of curves is adjusted to the speed so that the centrifugal force and the force of gravity are kept approximately in equilibrium and the engines are properly counterbalanced, the line will take care of itself."

R. Trimble, Pennsylvania Lines:

"Replying to your favor of May 28 in regard to work assigned to the Tie Committee, I can only make some suggestions:

"(1) Examine literature on the subject, especially proceedings of various International Railway Congresses.

"(2) Investigate what proportion of the axle load or loads is carried by individual ties under different weights of rail, with different kinds of ballast.

"(3) Investigate all variations that take place in the road on ties and ballast.

"(4) Investigate as to whether increased length of ties would be of any value.

"In regard to determining the size of ties, I think we have to be governed largely by our experience. At the same time efforts should be made to secure some rational solution."

A. W. Thompson, Third Vice-President, Baltimore & Ohio:

"Your letter of May 28 requesting recommendation in regard to the continuance of study of stresses on ties and the determination of the size required.

"Question No. 1—Along what line do you recommend the continuance of the 'study of stresses to which cross-ties are subjected?'

"Excepting losses from decay and fire and damage in wrecks and floods, tie renewals become necessary by reason of their checking and splitting, crushing under the rail and breaking at the ends and in the middle. These three failures are due to both internal and external stresses occurring during seasoning and as a result of impact, rolling load, and uneven tamping.

"It would be my recommendation, therefore, to continue the study

of stresses in ties along such lines as would reduce checking, crushing, and breaking to a minimum.

"Question No. 2—How would you 'determine size required' for cross-ties, and is such determination capable of rational solution?

"Where ties of small sectional area have been used, the cost of maintaining proper spacing and surface has been excessive. I should prefer a tie of larger sectional area whose dimensions would be dependable largely on the kind of ballast used. The width of a tie should provide sufficient bearing area to resist mechanical wear, and the thickness should be sufficient to resist any breaking due to uneven tamping.

"Too many indeterminate factors enter to make the size of the tie capable of rational solution."

W. B. Storey, Jr., Atchison, Topeka & Santa Fe Railway System:

"Your file S-55, May 28.

"First—There should be a search for some method by which the weights which are applied to track can be segregated so that we may know what we have to sustain both on the tie and on the ballast.

"Second—Determination of the size required can only be reached by observation and by compilation of data already in existence, until such time as a determination of the stresses in the tie can be worked out.

"There are many roads which use a 7-in. x 8-in. tie, other roads which use a 6-in. x 8-in., and some a tie as thin as 5 in. With certain kinds of wood, as, for instance, Redwood on the Pacific Coast, the 7-in. dimension does not give any too good results so far as breaking of the ties is concerned. A 6-in. tie under identically the same traffic conditions would be amply sufficient if of white oak or other hard wood.

"Any data that can be gathered on these various subjects will be of interest, and its publication will be of benefit."

A. H. Rudd, Signal Engineer, Pennsylvania Railroad:

"Replying to your letter of the 28th inst., in connection with topic assigned to the Tie Committee of the American Railway Engineering Association, namely, 'Continue study of the stresses to which cross-ties are subjected and determine size required.'

"I have to advise that this is a technical subject with which I am not sufficiently familiar to give you any opinion that would be of value."

L. C. Fritch, Chicago Great Western Railway Company:

"Replying to your letter of May 28 in regard to study of stresses to which cross-ties are subjected and determining size required, I beg to advise that this study should proceed along the lines set forth in Mr. Cushing's translation of the French article on track stresses which was published about a year ago in Proceedings of the Association.

"It is my opinion that we can assume certain conditions of ballast, rail, and load which will determine scientifically the size and number of cross-ties which should be used under modern traffic conditions."

Hunter McDonald, Chief Engineer, Nashville, Chattanooga & St. Louis:

"Referring to attached file S-55, May 28, from Chairman of Sub-Committee "B," Tie Committee, American Railway Engineering Association, giving questions on stresses in track ties.

"Would answer these questions as follows:

"(1) Would recommend the continuance of study of stresses to which cross-ties are subjected, along the line of a paper by C. Bräuning, pp. 267-285, Proceedings of American Railway Engineering Association, 1912.

"(2) The size of track ties should be capable of rational solution. After first determining the width and spacing required for tamping, the depth and length should be determined from the stresses developed by carrying capacity under impact of the ballast in which they are to be used. The carrying capacity under impact should be determined, experimentally, from the load that can be repeated indefinitely without causing sinking of the tie into the ballast after it has formed a firm bearing."

Chas. S. Churchill, Chief Engineer, Norfolk & Western:

"I have your letter of 28th ulto. asking for suggestion as to how your Committee should handle the study of stresses to which cross-ties are subjected, etc.

"As the Pennsylvania Railroad people have done a large amount of work in this matter, I think you should secure their records. I find that Mr. Cushing wrote Chairman Downs on May 2 on this subject, and I think you would do well to follow out his suggestions.

"Mr. Cushing further calls attention to the fact that there was an article on this subject in the Engineering Review, for Dec. 15, 1911, 104 High Holborn, London, W. C., England."

C. F. Ford, Rock Island Lines:

"Your letter of 28, file S-55, to Mr. J. B. Berry, has been referred to me.

"The investigations which have been made by the Tie Committee along the lines of study of stresses to which cross-ties are subject have been very thorough, and I regret that I can not at this time offer any suggestions on the proposed line of work for this year."

EXHIBIT C.

From William J. Wilgus:

"I have looked over the correspondence, which I return herewith, and really cannot add very much to the subject beyond saying that the views expressed in my letter to you of June 1 last (see Exhibit B-8) appear to harmonize quite closely with the general tenor of the replies of your other correspondents. To me, the study of the tie question should be directed more to an improvement in fastenings, drainage and ballast, and possibly improved types of general work construction, rather than to stresses, which are worthless unless founded upon well established bases, which in this case is not possible."

REPORT OF COMMITTEE IX—ON SIGNS, FENCES AND CROSSINGS.

C. H. Stein, *Chairman;*
R. B. Abbott,
H. E. Billman,
E. T. Brown,
J. T. Frame,
C. M. James,
L. C. Lawton,
G. E. Boyd, *Vice-Chairman;*
G. L. Moore,
J. B. Myers,
F. M. Patterson,
C. H. Splitstone,
W. F. Strouse,
W. D. Williams,

Committee.

To the Members of the American Railway Engineering Association:

The following subjects were assigned by the Board of Direction for consideration:

(1) Report on the relative advantages of the different kinds of fence posts, with definite recommendations.

(2) Report on the best form of track construction and flangeways at paved street crossings and in paved streets, with definite recommendations.

(3) Continue the investigation of ways and means for securing a proper quality of fence wire to resist corrosion and secure durability.

Your Committee has corresponded with the various railroads of the United States, as well as the manufacturers of material, and has also endeavored to learn the practices of foreign countries. It now begs to submit the following report:

(1) RELATIVE ADVANTAGES OF THE DIFFERENT KINDS OF FENCE POSTS.

Replies were received from 44 railroads, with the following information as to kind of post used, cost, life of same, etc.:

It will be observed from the foregoing that the various roads use the different kinds of timber indigenous to their geographical position as follows:

Cedar	32
Chestnut	7
Locust	9
Oak	9
Bois D'Arc	5
Catalpa	1
Oregon Fir	1
Juniper	1
Tamarack	1
Burnettized Pine	1
Mulberry	1

GENERAL INFORMATION ON WOODEN FENCE POSTS.

	Railroad.	1 Kind of Post.	2 Life of Post.	3 Cost of Post.	4 Destroyed by Fire.
1	Alberta Central	Tamarack & Cedar.		19.95c	
2	A. T. & S. F. System	Cedar & Bois D'Arc.	15-25 Yrs.	15c	
3	Balt. & Ohio	Cedar, Locust & Chestnut	12 Yrs.	Cedar 15½c Locust 15c Chestnut 12c	None.
4	Bangor & Aroostook	Cedar.	15-20 Yrs.	8-12c	1%
5	uff., Roch. & Pittsburgh	Cedar.	18 Yrs.	18c	Very Small.
6	Canadian Pacific	Cedar.	15 Yrs.	11c	Very Small.
7	Central of New Jersey	Chestnut.	14 Yrs.	18c	
8	Chicago, Burlington & Quincy	Red Michigan Cedar.			
9	Chicago Great Western	White Oak.	10 Yrs.	40c	
10	Chicago, Peoria & St. Louis	White, Post & Pin Oak. Honey Locust & Cedar.	Oak 5 Yrs. Locust 7 Yrs. Cedar 15 Yrs.	11c	30%
11	Cincinnati, Hamilton & Dayton	Cedar.		13½c	
12	Cincinnati Northern	White Cedar.	12 Yrs.	15c	1/6 of 1%
13	Cleveland, Akron & Cincinnati	Locust & Chestnut.		Locust 16-18c Chestnut 10c	Considerable.
14	Denver & Rio Grande	Red Cedar.	15 Yrs.	25c	
15	Duluth & Iron Range	Cedar.	15-20 Yrs.	12c	3%
16	Duluth, Missabe & Northern	White Cedar.	17 Yrs.	12c	
17	El Paso & Southwestern	Burnettized Pine.			
18	Fort Worth & Denver City	Bois D'Arc.	25 Yrs.	15c	Small.
19	Grand Rapids & Indiana	Cedar.	17 Yrs.	10½c	5%
20	Illinois Central	Red Cedar.	10-18 Yrs.	16-18c	
21	Kanawha & Michigan	Cedar.	15 Yrs.	20½c	1%
22	Kansas City Terminal	Cedar.		7½ Split 14c 10' Round 40c	
23	Lake Erie & Western	Cedar.	10-15 Yrs.	15c	
24	Lake Shore & Michigan Southern	Cedar.	20 Yrs.	15c	
25	Long Island	Yellow Locust.	15-20 Yrs.	38c	5%
26	Louisville & Nashville	Red Cedar, Black Locust & Catalpa.	10-25 Yrs.	15-25c	5%
27	Maine Central	Cedar.	15 Yrs.	10c	Very Small.
28	Mississippi River & Bonne Terre	Northern Yellow Cedar. Southern Red Cedar.	15 Yrs.	16-20c	2-3%
29	N. Y. C. & H. R.	Cedar & Chestnut.	Cedar 17 Yrs. Chestnut 13 Yrs.	8-17c 10-27c	1¼%
30	N. Y. N. H. & H.	Chestnut.	10 Yrs.	12c	No Record.
31	Norfolk Southern	White Oak & Red Cedar.	7-9 Yrs.	20c	Small.
32	Norfolk & Western	Locust.		15c	
33	Penn. Lines West, S. W.	Red Cedar.	15 Yrs.	25c	
34	Penn. Lines West, N. W.	Red Cedar, Locust & Chestnut.	15 Yrs.	25c	
35	Philadelphia & Reading	Chestnut.	10-15 Yrs.	15-25c	Very Small.
36	Quebec, Montreal & Southern	Cedar.	15 Yrs.		Less than 1%.
37	Richmond, Fred'burg & Potomac	Red Cedar & Yellow Locust.	Cedar 20 Yrs. Locust 30 Yrs.	20-28c	Very Small.
38	Rock Island Lines	Oak, Cedar & Bois D'Arc.	Oak 8-15 Yrs. Cedar 15-30 Yrs.	7' 13c 10' 22c	
39	St. Louis Southwestern	Mulberry, White Oak & Bois D'Arc.	Mulberry 15-20 Yrs. White Oak 10-12 Yrs. Bois D'Arc 45 Yrs.	13-17c	
40	San Pedro, Los Angeles & Salt Lake	Native Cedar or Oregon Fir.	8-12 Yrs.	16-21c 5c for Split Pile Ends.	Good Many.
41	Spokane International	Cedar.		8-12c	
42	Spokane, Portland & Seattle	Cedar & Juniper.	Cedar 8 Yrs. Juniper 15 Yrs.	Cedar 7c Juniper 8c	None.
43	Texas Midland	Bois D'Arc.	Indestructible.	15c	1%
44	Western Maryland	Locust.	20 Yrs	40c	

There are certain species of each of the above woods that are not suitable for fence posts, but doubtless must be used because they are cheap and native to the locality. This is indicated by the following summary drawn from the preceding table:

LIFE OF POSTS.

Red Cedar	7	to 25	years
Cedar	10	" 30	"
White Cedar	12	" 17	"
Chestnut	10	" 15	"
Locust	7	" 20	"
Yellow Locust	15	" 30	"
Black Locust	10	" 25	"
White Oak	7	" 15	"
Bois D'Arc	12	" 45	"
Catalpa	10	" 25	"
Juniper		15	"
Mulberry	15	" 20	"

Doubtless some give little heed to the particular species of such timber that they use, and assume that any species of that genus has about the same life. This is manifestly incorrect as is demonstrated by the oak family. The inferior grades of oak have only a life of from 2 to 4 years, while a good white oak has a life in our northern climates of from 10 to 12 years at least. Certain classes of oak last much longer in their native regions than in other localities to which they are transported for use. This principle applies with equal force to every other class of timber.

In reviewing the replies of the various roads we find that the consensus of opinion, based upon experience of the users, is that the different classes of timber have an average life as indicated below:

Red Cedar	18 years
White Cedar	15 "
Chestnut	12 "
Yellow Locust	20 "
Black Locust	20 "
White Oak	10 "
Bois D'Arc	25 "
Catalpa	15 "
Juniper	15 "
Mulberry	15 "

Climatic influences have an important bearing upon this phase of the case, and may lengthen or shorten the life of a particular kind of wood, dependent upon locality in which used. It is not feasible in most cases to recommend any particular kind of timber for a given territory, as the source of supply may be so distant as to preclude its use economically. It is the prevailing practice to use such timber as is

native to the country and thus most easily obtainable. According to information received, the cost of the various kinds of woods posts is:

	Range.	Average.
Red Cedar	15c to 25c	22c
Cedar	7c " 20c	14c
White Cedar	12c " 15c	14c
Chestnut	10c " 27c	20c
Locust	15c " 40c	25c
Yellow Locust	20c " 38c	30c
Black Locust	15c " 25c	20c
White Oak	11c " 40c	20c
Bois D'Arc	13c " 17c	15c
Catalpa	15c " 25c	20c
Juniper	6c " 10c	8c
Mulberry	13c " 17c	15c

It will be observed that the relative cost to life of post ranges from one-half cent to two cents per year of life, the Bois D'Arc and the Juniper being the cheapest posts, but so rare that a more general use is impossible.

It was of interest to know to what extent wooden posts were subject to destruction by fire. Replies received indicated that this varied by from 1 per cent. to 5 per cent., with the exception of one road which reported a loss of 30 per cent. from this cause. We think it fair to assume that the average loss by fire is around 3 per cent.

Only two roads so far as we can learn make mention of having used any metal posts, and then but to a limited extent. In the one case bar iron ¼ in. x 2 in. was used and in the other old boiler tubes. We have reason to believe, however, that quite a number of roads, not replying to our circular, are trying out a proprietary metal post. Several styles of steel right-of-way fence posts are on the market. Their exploitation has just begun in the last year or two, and any statement as to their efficiency and economy could be but vague and from the manufacturers' standpoint alone. Greater experience may demonstrate their utility, but thus far we have no data upon them, and can only give some computations from one of the manufacturers, which might be of interest for study from the viewpoint of railroad economy. These figures, while prepared for a certain style of post only, if reliable, will no doubt be equally accurate for any other style of metal post, built along similar lines, and others are generally so designed. In order that the membership may have the manufacturers' explanation of the merits of the steel post for their further consideration, we give the statement of the case in substance according to one with whom we have had the matter under discussion:

Steel Posts cost	23.03 cents
Cost of setting	1.30 "
Total	24.33 "
Estimated life	30 years

Based upon above figures, steel posts set one rod apart cost 81 cents per year.

The cost of setting wood posts is estimated at 5.8 cents each. The following table is based on wood posts costing from nothing up to 20 cents each, and is intended to show what the life of wooden posts must be at different first costs to be as cheap as the steel post:

Cost of Post.	Cost of Setting.	Total Cost.	Years it must last to be as cheap as steel.
0 cents	5.8 cents	5.8 cents	7.1 years
5 "	5.8 "	10.8 "	13.3 "
8 "	5.8 "	13.8 "	17. "
10 "	5.8 "	15.8 "	19.5 "
12 "	5.8 "	17.8 "	21.9 "
15 "	5.8 "	20.8 "	25.6 "
17 "	5.8 "	22.8 "	28.1 "
18.53 "	5.8 "	24.33 "	30. "
20 "	5.8 "	25.8 "	31.8 "

The above figures would indicate that wood posts costing 15 cents would have to have a life of 25.6 years and those costing 20 cents a life of 31.8 years to be as cheap as steel.

The first steel posts are said to have been manufactured about fifteen years ago at Bloomfield, Ind. Others, doubtless, of different design unknown to the Committee were manufactured as long ago and perhaps longer, but only during the past twelve years have they been given any serious study with a view to placing them on the market for ordinary right-of-way fencing. Hundreds were taken up and examined to discover signs of rust, and deterioration at ground line or elsewhere. They have been in use at Spencer, Worthington, Bloomfield, Ind., and elsewhere in all kinds of soil and under all conditions. The investigations have resulted in placing them on the market during the past year or so.

To be of economic worth for right-of-way protection, a fence post must possess the following qualities: Durability, Practicability, Efficiency and the price must be right. Inquiry develops that one man can set in a day from 15 to 35 wooden line posts. To be conservative, 30 posts per day per man is assumed as the unit of work. Estimating wages at $1.75 per day places the cost of setting a wood post at 5.8 cents. The cost of post is estimated at 12 cents, resulting in an entire outlay of 17.8 cents. Experience is to have demonstrated that three men can readily set from 390 to 640 steel posts per day, or 130 to 213 per man—130 posts per man is taken as the basis of calculation with wages at $1.75 per day. This places the cost for setting a steel post at 1.3 cents. Cost of steel post 23.03 cents, plus cost of setting 1.3 cents, resulting in entire outlay, 24.33 cents.

COMPARATIVE COST OF STEEL AND WOOD.

Entire cost of steel post 24.33c; estimated life 30 years.
Money worth 6 per cent.
Entire cost of wood post 17.80c; estimated life 12 years.

Expenditure for steel posts	24.33 cents
Expenditure for wood posts	17.80 "
Difference	6.26 "

Compound interest on 6.26 cents for 12 years amount to 13.06 cents. At the expiration of 12 years wood posts have failed and need renewal. 13.06 cents has been saved over cost of steel posts. This is equivalent to purchasing 8.8 years more protection with wood. In other words, 24.33 cents expended for steel give 30 years of protection, while same amount expended for wood gives 12 years original life, plus 8.8 years interest on investment, or 20.8 years, a balance in favor of steel of 9.2 years. Viewing the matter from another angle, assuming that posts are set one rod apart, track protection costs per year as follows:

Steel Posts.		Wood Posts.	
Per Rod	$ .0081	Per Rod	$ .0117
Per Mile	2.59	Per Mile	3.74
Per 100 Miles	259.00	Per 100 Miles	374.00

Balance in favor of steel posts of

$ .0036	per rod per year.
1.15	per mile per year.
115.00	per 100 miles per year.

Other advantages claimed are no staples used; right-of-way may be burned over from time to time without injury to posts. No loss from accidental fires and no renewal on that account. Special end, corner and gate posts must be used in connection with the steel line post. No means are provided for bracing them so as to use them as end or corner posts. There is not enough steel in them to stand the strain of stretching a heavy wire fence. The minimum amount of steel is used necessary to meet requirements of a right-of-way fence. The line and end posts are treated as distinct problems. In this they are not unlike posts made of other materials. The demands on the end and corner posts are entirely different from those on the line posts. The line post should possess a certain degree of flexibility, while end and corner posts must be absolutely rigid.

COMPARATIVE COST OF STEEL AND WOOD END AND CORNER POSTS:

Cost of End Post	$1.62
Cost of Corner Post	2.30

Assuming it fair to say that twice as many end posts will be needed as corner posts, it places the average of the stretching post at $1.84 each. If $1.84, the cost of the steel corner post, bears the same relation to the cost of a good wooden corner post that the price of the steel line post bears to the price of the wooden post, then the economy is demon-

strated. In order to determine whether or not this relation maintains, we resort to the following equation:

$$\frac{12c \text{ (cost of wood line post)}}{23.03c \text{ (cost of steel line post)}} = \frac{\times \text{ (cost of wood corner post)}}{\$1.84 \text{ (cost of steel corner post)}}$$

We find $\times = 96$ cents, cost of wooden corner post, which appears to be a conservative estimate of the cost of a good wooden corner post. From a mathematical and perspective point of view, the manufacturer of the steel fence post appears to have made out a case that is worthy of continued and further close investigation. Time alone, under practical service conditions, can demonstrate if the figures are based upon substantial premises, and subject to corroboration. To be efficient and adequate, the steel posts must resist corrosion, must be sufficiently strong to withstand ordinary and accidental hard usage, must not heave from the ground in Winter, must remain firm and not loosen up, permitting fence to get out of proper alignment. The speedy extinction of our forest lands, the failure on the part of all concerned to encourage the practice of reforestation, hence its slow progress, which idea will some day receive more earnest consideration than now, but too late for the next generation to profit by it, caused the users of wooden fence posts to seek some efficient substitute. The steel fence post has not yet proved its merit in practice and at this time concrete with suitable reinforcement seems to offer the only solution to the problem. A growing appreciation of the rapid depletion of our woodlands, and the urgency of discovering a suitable material to replace that which is now so near extinction, has during the past several years enkindled a livelier interest in the experimentation with and development of the proper form of concrete fence post. The problem is simply one of design. It is recognized as a primary proposition that in order to secure a post of such weight that it can be readily handled, practically as easily as wood, that it must not be too heavy; hence, reinforcement is necessary to reduce the bulk of concrete. This reinforcement must bear a co-ordinate relation to the concrete and act in harmony with it. To produce this result it must be properly placed, and make a proper mechanical bond with it. It has been demonstrated that while concrete posts are not as strong as wooden ones, yet they are sufficiently so to meet all practical conditions. It has been a generally accepted fact that wooden posts are stronger than necessary, rather than that concrete posts are not strong enough. Furthermore, it is true that there is quite a period of time in the case of wooden posts before they have decayed to such an extent as to actually require renewal, during which they are no stronger, in fact, not as strong as a properly designed concrete post. The latter has the advantage, so far as present investigations have proceeded, that its strength increases with age. It is true that many forms of concrete posts have been put on the market that had no utility whatever. Such, however, has always been the experience with any new development, and we are profiting by the failures of the pioneers in the industry.

The present progress of the art has reached a stage where some assured results are being obtained, and such railroads as have given the matter study have begun to use designs which are very promising in their prospects. Your Committee believes that it has been a misfortune that the interest of the railroads was not awakened in this industry many years ago, so that investigations could have been more actively pursued before an actual necessity confronted them. Such roads as have been relying on Chestnut timber lands for their supply of fence posts will have to almost immediately resort to something else, as the blight recently affecting Chestnut timber is becoming almost continental in its ravages. Virgin forests of Chestnut that were held beyond price only two years ago in the East are now being offered at a sacrifice in order to retard the progress of the destroying agency, and get some use of the timber before it becomes worthless on the stump.

It seems to have been a fact that the farming communities were the first to become alarmed at the decadence of our wood lands and hence the first investigators of a suitable substitute for wooden fence posts. Essentially their investigations were not conducted along the lines of proper structural design; impetus was added to the investigations, however, but a few years ago when the railroads by virtue of necessity became interested.

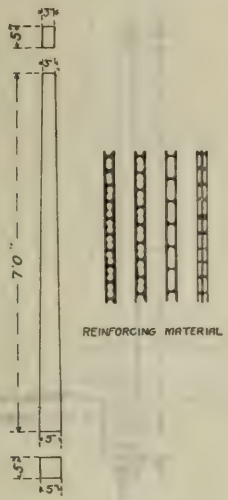
Your Committee has gotten into touch with the various manufacturers of concrete fence posts, as well as the various railroads that are experimenting with them, so far as has been possible, and will endeavor to present some data relating to them. Not more than a dozen railroads are using concrete posts at this time in large quantities, but a large number are pursuing the subject with a view to their extensive use. In deference to some manufacturers, we would state that we have not be able to present cuts of all the different designs because of inability to secure plans or photographs, and in the case of those presented, the information is not as full as we would have desired for similar reasons.

DESCRIPTION.

"A" posts are 7 ft. long, and are usually made 5 in. x 5 in. at the bottom and 3 in. x 5 in. at the top. Reinforcing material consists of steel bars with a series of perforations. It is a waste product produced in the manufacture of machinery and is only considered scrap. It is sold for from 1¼ to 1½ cents per pound. The perforations, size, etc., are assorted, unless purchaser demands uniformity, in which event higher price is charged. Cost ranges from 20 cents to 35 cents per post, depending upon size, local conditions, proportion and quality of material.

"B" posts are made in lengths of 6½ ft. to 8 ft., are 3 inches square, and do not taper from butt to top, claim being made that taper is not necessary. Wire fence is fastened to post by winding an independent or tie wire around post by Western Union twist method. Reinforcement consists of a piece of No. 20 gage sheet-steel, cut in six-inch widths

TYPES OF CONCRETE FENCE POST



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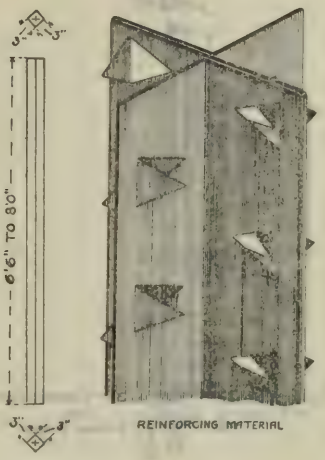

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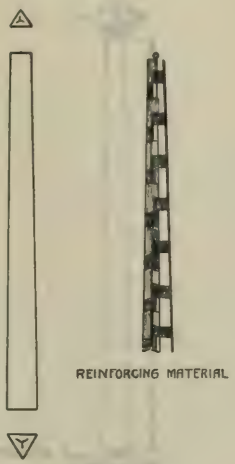

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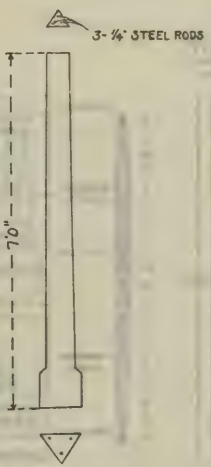

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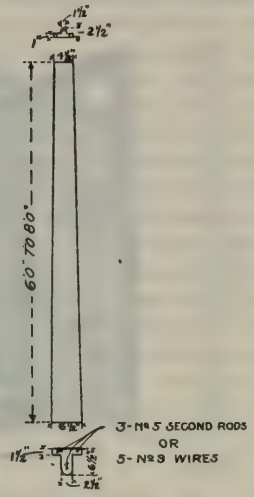
TYPES OF CONCRETE FENCE POSTS.



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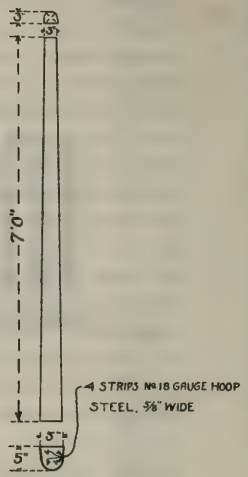

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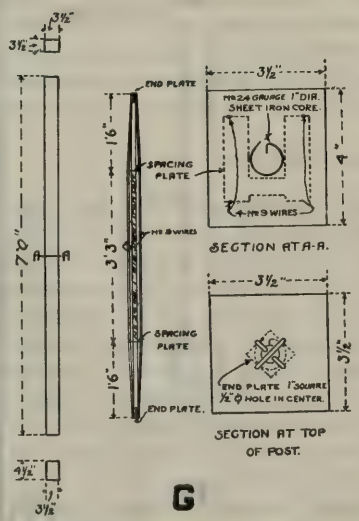

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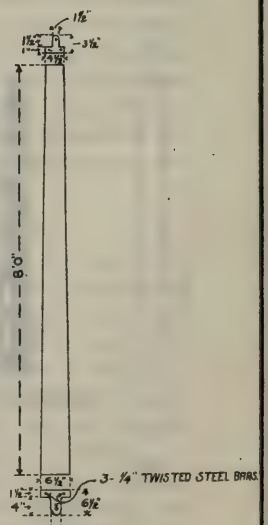

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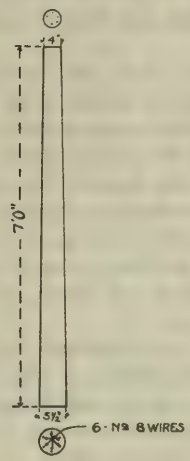
TYPES OF CONCRETE FENCE POSTS.



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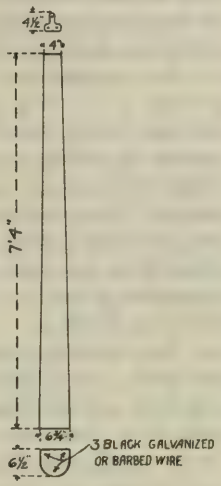

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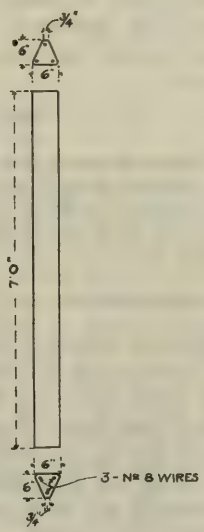

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(3)

and pressed as shown, giving a full eight inches of resisting face. Reinforcement for a 7 ft. post weighs 5 lbs. Posts are set with corner toward fence wire. They will thus stand considerably more of a shock received in a line perpendicular to the fence line or parallel therewith, on account of the increased depth of the concrete and the manner in which the reinforcement is placed in the post.

Post weighs 59 lbs., stands a load of 900 lbs. when supported on a span 42 in. long before cracking the concrete, will deflect 0.66 in. and not break concrete until load reaches 1,400 pounds. They should remain in molds long enough for the initial set, from 8 to 24 hours. They should at no time be laid upon the ground, but should be stood upright. This will prevent danger of checking or cracking. Posts should not be handled while green as a strain from lifting, or a slight jar, will cause them to crack. They should be sufficiently cured in 5 to 10 days to permit piling, but should not be used for about 30 days, 60 days would be better.

Soft soap or crude oil should be used sparingly to grease molds; too much grease destroys the setting of cement. A small amount of oil put in a pail of water applied with a mop or soft broom to the molds after they have been used several times will prevent concrete sticking to the molds and making the posts rough and pitted.

Do not let concrete freeze. Intermittent placing of the concrete should be avoided or a continuous bond will be not be produced through the post. Wet mixture of a quaking consistency should be used instead of tamping a dry mixture. It makes posts 25 per cent. stronger, and will better withstand frost and alkali. Bonding of concrete to steel is said to be about 225 pounds per square inch; 1,600 to 2,000 posts can be loaded into one car.

COST.

Material and Labor.	Cost.	No. of Post.	Cost. Per Post.
1 yd. (Gravel, crushed rock, chat or sand)	$0.75	80	.009
1 bbl. (4 sacks cement) (380 lbs.)	1.25	48	.026
1 No. 20 gage sheet steel reinforcement	.083	1	.083
2 men, $1.50 per day	3.00	300	.010
Total cost per single post			.128

"C" posts are made in lengths desired, are triangular in section and reinforcement is a combination of pressed steel and steel rods. The molds or forms, of which there are two, are raised to and held in a vertical position, top of post down. Post tapers from bottom to top. The concrete is tamped by gravity, the settling and compacting being accomplished by constant jar of the mold during process of making post. The mold is lifted automatically and let drop on a solid foundation, continuing this motion as it receives the concrete.

"D" posts are made 7 ft. long and weigh from 50 to 60 lbs. Reinforcement consists of three ¼ in. rods. Post is triangular in form and

rods are placed one in each corner, tied together at short intervals by perforated core plates. Advantage claimed for this form of post is that reinforcement may be increased by increasing number of perforations in core plates and adding reinforcing rods. Post is said to have withstood a test of 1,088 pounds, supported at both ends, without any deflection. The manufacturers lay stress upon the fact that a staple receiving composition is introduced into this post, into which the common hard wood staples may be driven as easily as into wood.

"E" posts are made in lengths of from 6 ft. to 8 ft., varying by one-half foot to suit consumer. They are of "T" form and weigh from 85 to 90 lbs. They taper from bottom to top in every dimension. They are designed upon the principle of the "T" beam. Reinforcement consists of three No. 5 second rods or five No. 9 wires, cut and straightened and bent at right angles one inch from each end. Wires are slightly irregular in shape and are termed seconds, not because of inferior quality, but because they are pressed out of shape in manufacture, which produces better bond between them and the concrete. They are placed as near surface as possible, but exposure must be avoided. No device is used in placing them. Figures given below are for average conditions of cost of raw material for posts 7 ft. in length.

In quantities over 150 posts per day, concrete power mixed:

Material	Cost.	Will Make.	Cost per Post.
1 Yard gravel, crushed stone, sand	$ 0.75 per yd.	40 posts	$0.0188
1 Barrel cement	1.12 " bbl.	24 "	.0466
1 Ton reinforcing	40.00 " ton	800 "	.05
2 Men	3.50 " day	150 "	.0233
Total cost per post			$0.1387

In quantities less than 150 posts per day, concrete hand mixed, the total cost per post averages $0.1581.

The above is based on a 1 to 4 mixture. Hydrated lime is frequently used to the amount of 10 per cent. and increases ultimate strength, makes post lighter in color and water-proof. It is claimed that 99 per cent. of failures in posts is due to the fact that concrete is tamped instead of being a slush mixture. Posts should be kept in shade during period of curing for at least 20 to 30 days. Sprinkling posts greatly aids curing and prevents tendency of concrete to check, as happens when exposed to sun while being cured. When posts are to be much handled or shipped, they should not be touched for at least 60 days. Posts are made in batteries of 20 and 30 molds. Wire fence is fastened to posts by a tie-wire one size smaller than the corresponding wire in the fence proper, which passes around post with a Western Union twist.

"F" posts are tapering, practically square in cross-section, being made in "U" shaped molds, with round back corners leaving flat face. The regular size line post tapers from 5x5 in. at base to 3x3 in. at top in lengths of 7, 7½ and 8 ft. Supplied also with a 5½ in. base and 3½ in top, as well as 6 in. base and 4 in. top in 7½ and 8 ft. lengths,

respectively. The regular 7 ft. line post, 5x5 in. at base and 3x3 in. at top, weighs 80 lbs. (½ in and 1 in. size larger posts are about ⅛ and ½ larger respectively, than regular.)

Reinforcement for regular line posts, four lengths of ⅝ in wide, No. 18 gage hoop steel, or No. 5 wire rod "seconds," placed at corners or turns, and about ¼ in. from the surface, full length of post. (Other sections of steel single, stranded and fabricated forms also used, varying according to size of posts). (No. 5 wire rod "seconds" referred to are imperfect in shape only, being slightly imperfectly round).

Advantages claimed for hoop reinforcement is that being a standard mill product, it can be readily purchased in open market, and is quickly placed in desired positions in the filled molds, by use of automatic (or placer) device furnished, after molds are filled full. Superior to the same weight of wire, round or square rods as presenting a much greater surface for the concrete to adhere to; other shapes than hoop require placing the reinforcements by hand as molds are slowly filled in layers. Advantage of No. 5 "seconds" (over other than hoop) is the low price at which it can be purchased (ultimate cost in post comparing favorably with hoop).

Cost below shows varying cost per post, due to difference in price of raw materials, labor, etc., for a regular 7 ft. line post:

Material.	Cost.	Will Make.	Cost per Post.
1 Yard gravel	$0.20 to $0.60	40 posts	$0.005 to $0.015
1 Barrel Cement	1.00 " 1.50	24 "	.04 " .06
3 or 4 reinforcements, 2 lbs. to 3 lbs	.02 " .03	1 "	.05 " .09
2 Men, one hour, 20c to 25c per hour	.40 " .50	15-20 "	.025 " .03
Total cost per single post			$0.12 to $0.195

This cost is based on a one to four mixture.

These post machines consist of batteries of 6 and 10 molds each, the latter recommended for large capacity plants. Also 20, 30 and 50 mold trucks for steam curing or economy of transportation.

Method recommended for fastening wire or fencing to posts is by using short pieces of galvanized soft wire, No. 12 or 13 gage, placed around the back of the post, and twisted to the line wires of the fence on each side of the post, with a simple device furnished with the wires. The tie wires are prepared with hook upon one end for convenience and speed, it being understood that the wire or fencing is placed against flat side of post. Anchor posts should be set every 60 to 80 rods.

Concrete must be made as a wet mixture about the consistency of mortar for wall plastering. When molds are filled the concrete is set in vibration longitudinally by shoving the mold bed of six or ten molds back and forth for fifteen or twenty seconds at intervals, the molds being supported upon vertical springs for this purpose, also supporting the molds right height for ease of filling. This shaking settles and compacts the concrete, and gives the post a smooth, dense, practically water-proof, surface.

Posts should remain in molds from six to 24 hours, to take initial setting, when they may be removed upon soft level ground, when after being kept wet by sprinkling for several days, they should be sufficiently cured to pile upon end to economize space. It is preferable to make and cure posts in a shady place or building. Posts should be seasoned 60 days before using. If steam curing is used, posts will be sufficiently cured in 48 hours to pile, and to use in 30 days. Posts should not be made in freezing weather unless steam curing is used.

"G" post is square in form, with slight taper on two sides from bottom to top. It is 7 ft. long, 3½ in. by 4½ in. at bottom and 3½ in. by 3½ in. at top. Reinforcement consists of center tube of 24 gage black iron, 75 in. in length, with four No. 9 wires tensioned over tub. Truss plates or spreaders engage the four wires in tension. Concrete should consist of one part cement to five parts clean, sharp sand. It should be thoroughly mixed and sufficient water used to give concrete a slush or mortar consistency. Molds should be filled with slush concrete and reinforcement be imbedded thereafter. Posts should be removed from molds the day after manufacture and placed in an upright position for curing. Posts should be cured at least 30 days before using.

COST UNDER AVERAGE CONDITIONS OF A 7 FT. POST:

Concrete	$0.07
Reinforcing	.15
Labor	.03
Total cost per post	$0.25

Post was tested when four days old and did not crush until a weight of 800 lbs. evenly distributed, was applied, post being supported at each end.

"H" posts are "T" shaped, are 6½ in. by 6½ in. at bottom and 4½ in. by 3½ in. at top and 8 ft. long. Reinforcement consists of three ¼ in. twisted steel bars, placed in the three corners of post.

"I" posts are circular in form, tapering from bottom to top. Bottom diameter is 5½ in., top diameter is 4 in., and posts are 7 ft. long, weighing 121 lbs. Reinforcement consists of five or six (as desired), upright No. 8 crimped bright Bessemer wire, with No. 14 annealed cross wires to hold the uprights in place, and costs from $0.068 to $0.08 per post.

Various methods of fastening fence wire to post have been employed. Holes 5/16-in. in diameter are made through the post at stated intervals; in some cases 10 penny nails are passed through these holes and bent around the fence wire. In others a fastening wire is clinched around the fence wire, passed through the hole and twisted on back of post. A third method is to use a tie-wire around the post, fastening to fence wire with a Western Union twist. It is said that these posts can be made for not to exceed 18 cents.

"J" post is "T" shaped, but entirely with rounded corners, and is tapered from 4 in. at the top across the face, and 4½ in. from front to back, to 6¾ in. across the face at bottom, and 6½ in. from front to back. Posts are 7 ft. 4 in. long. Another feature is a foot or extension on that part of the post imbedded in the ground. Reinforcement consists of black, galvanized or barbed wire to suit maker, placed as near the outer portion of post as possible. The consistency of the concrete must be a quaking mixture.

Any one of the various methods of attaching fencing wire may be employed. One method is to set staples in post at gage to correspond with spacing of fence wire at time it is made. Another is the frequent custom of using a tie-wire around post with a Western Union twist. These posts are said to cost about 15½ cents each.

"K" These posts were among those suggested by the United States Department of Agriculture. They are triangular in form, each side being 6 in. wide, with all corners rounded and 7 ft. long. Reinforcement consists of three No. 8 wires, one in each corner of the post. Reinforcement is kept in place by a device called a fool-proof spacer. It consists of a No. 10 wire cut to such length that, when twisted once around each of two reinforcing wires, the ends will nearly touch the side of the mold. The distance from the twist to the end of the short wire is equal to the distance from the reinforcement to side of mold. In triangular molds such a spacer can be used only on the two wires near the top of mold. A shorter and similar device with only one twist may be used on the lower reinforcement. At least three spacers should be placed on each piece of reinforcement. Spacers should be placed three-fourths of an inch from the inside of mold. Wire fencing may be attached by any one of the approved methods.

For full information see Farmers' Bulletin 403, U. S. Department of Agriculture.

The Board of Water Supply of the City of New York is perhaps one of the largest users of concrete fence posts in recent construction work, intending to use 61,070 concrete posts of various approved designs to fence in the watersheds of the Catskill Aqueduct. The designs adopted by them are herewith submitted.

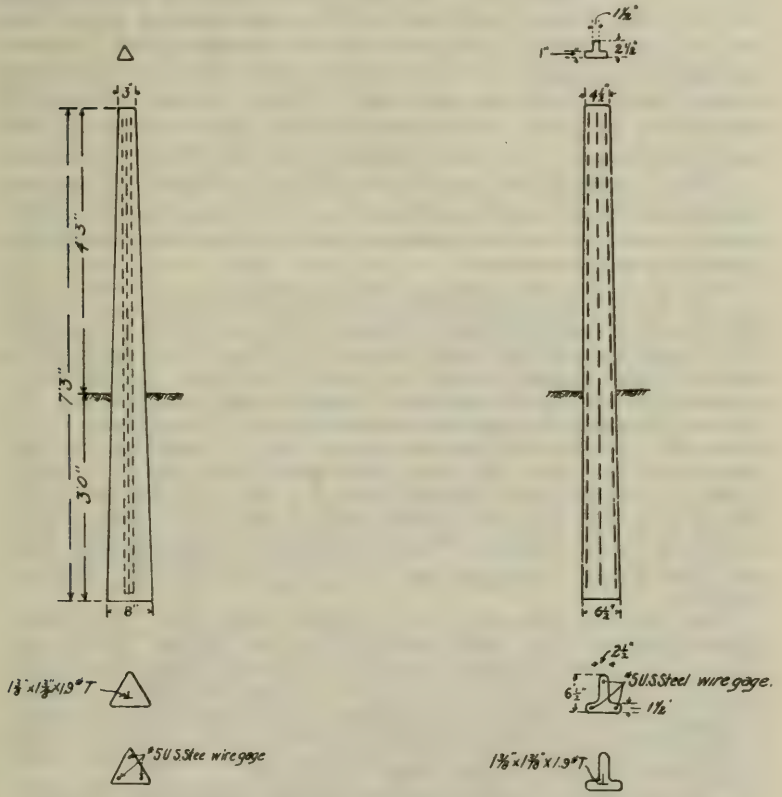
These posts are said to weigh from 110 to 120 lbs each. No data is obtainable in regard to cost per post. The Department Engineer stated that two general designs were adopted, one reinforced and the other steel core; the former for most general use, the latter more especially for those rock locations where blasting might not be desirable, the base being shortened as necessary, the steel projecting into a shallow hole drilled in rock. No commercial types were tested as a preliminary to their adoption, but were favored because of approving recommendations of previous users.

The Delaware, Lackawanna & Western Railroad reports that it uses the post designated as "F" in the foregoing sketches of various kinds

of concrete posts. They are made 5 in. by 5 in. at the bottom, 3 in. by 3 in. at the top and 7 ft. 6 in. long. Concrete is made of

1 part cement,
2 parts sand, and
4 parts stone (¼ in. to ½ in. size).

Reinforcement consists of four pieces No. 18 gage hoop steel. The cost of manufacturing the post at their plant is 15 cents each; loaded and packed in shavings and sawdust in cars 16 cents each.



DESIGN OF CONCRETE LINE POSTS USED BY BOARD OF WATER SUPPLY, CATSKILL AQUEDUCT.

Anchor posts are 8 ft. long, 7 in. by 7 in. at the bottom and 5 in. by 5 in. at the top, with nine pieces No. 18 gage hoop steel in each post. They are made from same mixture and cost about 24 cents each.

Fifty posts of another type with core reinforcement in center were manufactured, using same concrete mixture, and tested in comparison with the "F" type of post; supports were placed five feet apart, and weight applied at center. The "F" type of post cracked at 760 lbs. and

broke at 825 lbs. The core reinforced post cracked at 525 lbs and broke at 600 lbs., indicating approximately 40 per cent. more strength in the corner reinforced post than in that with the center core.

Another test was made on a 7 ft. span. The "F" type cracked at 425 lbs. and broke at 485 lbs. The core reinforced post cracked at 250 lbs. and broke at 300 lbs., indicating an advantage in favor of the "F" type of from 60 to 70 per cent.

Larger posts were made, placing wire netting and bars as reinforcement and it was found that the hoop steel properly placed, one piece in each corner of the post, made the strongest post. Further investigation was made and it is now the opinion that instead of using a post 3 in. by 3 in. at top and 5 in. by 5 in. at bottom, it should be made 3½ in. by 3½ in. at top and 5½ in. by 5½ in. at bottom, with same reinforcement. The report concludes with the following statement:

"What a concrete post will do from weather conditions has not been demonstrated to my entire satisfaction. We have, however, passed through one winter and two summers, and have had exceptionally fine results from field conditions."

The Mississippi River & Bonne Terre Railway reports: "Two years ago, and for two or three years prior to that, I experimented, making posts of several different patterns. The forms used were the square pattern recommended by the United States Department of Agriculture; a mold we made ourselves similar to type 'F,' but heavier; molds bought to make posts like type 'E' and molds bought to make posts like type 'F'; also a mold making a round post furnished by the Fence Supply Co. of Elburn, Ill. Of these different patterns a total of something less than 1,000 posts were made. They were set in various places along the right-of-way and fencing in a couple of tracts of a few acres adjacent to the right-of-way. The idea was to build fences using various types of posts so that after they had been in use a number of years we could more intelligently select a standard. Various kinds of reinforcing bars were used from ⅜-inch corrugated bars to No. 8 plain wire; also some flat hoop iron.

"We have an abundance of a material called chats. It is finely crushed limestone, from which lead ore has been washed. From some of the mills it passes through a six-millimeter screen, from others a nine-millimeter screen. It contains all of the fines below these sizes. It is quite similar to crushed limestone screenings. We have carried on tests for a number of years and find this material mixed with cement gives from 50 per cent. to 80 per cent. higher tensile strength than where cement and the same quantity of good, clean sand is used.

"For our posts we used a 1 part cement and 3 parts chats, and others 1 cement and 4 parts chats, while some we made using a mixture of sand and chats in about same proportions as above.

"My preference is the 'F' type mold, preferably using four reinforcing rods or wires for line posts. We use mostly No. 8 wire. When we make more will probably use No. 6 wire or perhaps three Havemeyer bars ¼-inch size.

"The U. S. Department of Agriculture mold and our own was discarded because the post was unnecessarily large and heavy, although the fence stands beautifully and is apparently straight and true as when built nearly four years ago.

"The Fence Supply Co.'s round mold was an interesting plaything and made a fairly good post. Though the method of placing the re-

inforcing wires is ingenious, we would not always depend on the wires being fully encased in the concrete.

"Between the 'E' type and 'F' type I prefer the latter for the following reasons:

"It is easier and takes a shorter time to make the post; it is not so difficult to get a smooth, dense post. We found with the 'E' type that it was difficult to condense the concrete and get a smooth post, though we used quite a wet mixture. It was also more difficult to place the reinforcing. We did not try the strength of posts by weighting in the middle with ends of posts supported, but it may be with equal reinforcing the 'E' type is the stronger. There is a little less material in the 'E' than the 'F' type. A batch that will make five 'F' posts will make six of the 'E' type. The 'E' type also has a much larger surface than the 'F' type. They, therefore, require more care and sprinkling so that they will not dry out too quickly. They also have more corners and are much more easily chipped and nicked in handling, although I cannot say they will break through easier than the 'F' type.

"I think the shaking feature of the 'F' type enough advantage to decide one in favor of that mold, for with it a smoother post can be made and more than enough time saved to overcome the slightly greater quantity of concrete used. We found we could not be sure of getting good posts without letting them set 3 to 4 days in the mold. Twice a week is as often as I think it safe to use the molds and then a smooth bed to lay the posts on and careful handling is required. For instance, using one ten or twelve-gang mold, we made posts Monday forenoon and Thursday afternoon and found it could not safely be done oftener.

"The most serious objection to the use of concrete posts, I feel sure, will be the transportation. With us we did not have to ship them far, thirty miles being the extreme distance. We laid them face down on a flat car, then another course face up between those laid face down and but the two layers on a car. More could probably have been safely shipped by using a layer of straw between, something as is done in shipping stock brick. Our total breakage in shipping and handling from mold to setting in fence line was less than 5 per cent., but it required a watchful foreman and careful men.

"A few of the 'E' type and 'F' type posts have been broken since the fence was built within the past two years. This was due to hunters and trespassers climbing the fence, probably purposely trying to break it down. On account of the more or less rough usage from irresponsible parties who trespass on railway lines, particularly in the western country, I favor strong reinforcing.

"For end and brace posts, where woven wire fencing is used, I think about a 6-in. by 7-in. by 8½-ft. post about right. We reinforced with twelve No. 6 wires. They are standing well. I believe, however, ¼ or ⅜ reinforcing bars would be better. We do not expect to use any more wooden posts. Most of the fencing we have done the past two years has been in way of repairs, using some posts when needed we had on hand.

"Next year I expect to again make concrete posts for needed fences, and I shall probably get more 'F' type forms and use them in preference to any I now know of. The line posts, 'E' and 'F' types, cost about 21 cents each. We made but few at a time, taking men from other work, so that it was a little more costly than had a gang been kept at it continually. I believe good posts can be made at from 16 cents to 20 cents each in this section of the country. The end posts were large and cost from 80 cents to 90 cents each."

The Illinois Central reports: "This company recently purchased a machine to make posts shown as type 'I' in the foregoing sketch. Before

purchasing the outfit we took occasion to investigate eight different concrete posts and post molds now on the market and decided that the best results were to be obtained from this machine.

"We estimate that one of the plants complete, ready for the manufacture of posts, would cost as follows:

Concrete machine	$ 750.00
1,200 molds, at $2.25 each	2,700.00
5 H.P. gasoline engine	200.00
Building	600.00
Total	$4,250.00

"With this plant it is estimated that we can make an average of 400 posts per ten-hour day with a working force of one foreman at $2.50 per day and six men at $2.00 per day, a total of $14.50 per day for labor.

"We expect to use a tapering, round post 7 ft. long, 5½ in. in diameter at the base and 4 in. at the top would be the proper dimensions. The advantages of a tapering post are lighter weight, cheaper because less material used, and it sets more firmly in the ground because the major portion of the weight is toward the bottom.

"Assuming that the plant would be operated 150 days per year, and taking into consideration 20 per cent. on the money invested to take care of interest, depreciation, maintenance, supplies, etc., the unit cost of manufacturing these posts is estimated as follows:

Concrete for one post	6.2 cents
Reinforcement	7.1 "
Labor, 400 posts daily	3.6 "
Interest, depreciation, expense of plant, etc	1.5 "
Total	18.4 "

"A post of the above dimensions will weigh approximately 100 lbs. Before being installed, this weight may be considered undesirable, but as soon as the post is set in the ground it is an advantage. The reinforcement consists of 5 strands of No. 8 wire. These are placed near the surface, where the post is called upon to resist the greatest amount of tension. I believe the fence wires should be fastened by looping them around the post.

"During the calendar year ending December 31, 1911, the cost of cedar fence posts purchased by this Company averaged 16.5 cents each, or only 2 cents less than the estimated cost of concrete posts.

"Estimating the life of the cedar posts which we are now getting as 15 years and that of the concrete posts as 40 years (which are both conservative estimates), the capital necessary to set aside at 5 per cent. compound interest, plus the first cost, would be as follows:

Kind of post.	Estimated life.	First cost.	Capital required to set aside to replace at 5% compound interest.	Capital required to set aside to replace plus first cost.
Cedar	15 years	$0.165	$0.152	$0.317
Concrete	40 years	0.184	0.031	0.215

"These plants are portable and can be moved at small expense.

"Among some of the advantages of the concrete post over the wooden post may be mentioned the fact that the component materials of a concrete post—sand, gravel and stone—are widely distributed and are easily procured in almost any locality, their indestructibility by fire, rot, rust or corrosion, their long lifetime and a neat appearance."

The Rock Island Lines report: "A good fence post should have the following qualities: Long life, possess sufficient strength to withstand the strains to which it may be subjected, and be obtained at a reasonable cost.

"A wooden post, while cheap, at the present time is gradually becoming scarcer and more costly each year, also has a short life and readily attacked by fire.

"A steel or iron post is readily attacked by water and gases, the cost being prohibitive for a great deal of the railroad work.

"A concrete post of the proper design will last almost indefinitely, is fireproof and admits of being made in almost any section of the country and at a fair cost by the proper proportioning of the reinforcing material which can be so designed as to secure the necessary strength. The stability is good on account of not being subject to the effect of fire, water, frost or decay.

"This road, after going into the subject thoroughly, decided that the circular section of post shown as type 'I' in the foregoing sketches was the best post for our work, not only the strength being considered, but rapidity of construction, life and cost of post.

"We have decided to use two sections of posts, a corner or gate post 5½ in. diameter at top and 7 in. diameter at base, and line posts, 4 in. diameter at top and 5½ in. diameter at base, all posts being 7 ft. long, placed 2 ft. 4 in. in the ground and 20-ft. centers.

"It is a well-known fact that there are concrete posts, plain and of various forms of reinforcement, which have been in use for years and are in just as good condition as when placed in the ground. The machine we have installed at Carlisle, Iowa, for making these posts is capable of turning out 500 finished posts per day, using a 1-4½ mixture of cement and coarse sand. The posts are made in a vertical position, and while molds are being filled they are given a vertical motion, which expels all air and forces the wet mixture into all parts of the forms, providing a good bond between concrete and reinforcement. The cost of the finished line posts is in the neighborhood of 20 cents at the plant. We place the reinforcement on the outer edge, so that the thrust, whatever it may be, will always be taken care of by the reinforcing wires in tension, using nine wires of No. 8 hard Bessemer wire in the larger posts and six wires of the same size in the smaller post, as shown by plan which is attached hereto. You will note that we have shown eight holes for binding wires. This spacing will admit of using either a hog-tight fence or cattle fence by fastenings.

"The design of a proper and satisfactory brace post and fastenings for corners and gate posts has been a very hard proposition. We use a 5-in. by 5-in. brace reinforced with six wires of same kind of reinforcement as used in the posts secured to the post by an iron band, as shown.

"Of course, in the construction of the fence it will be necessary to have a gang of men who will take due care in loading, unloading and erecting same.

"We expect to place a number of miles of this kind of fencing in position soon and probably can give you better information by the first of 1913 and shall be glad to do so, if you desire."

It has been exceedingly difficult to obtain any record of satisfactory scientific tests of the various kinds of posts, and your Committee sought information from every possible source. We were only able to secure the following interesting data through the courtesy of Professor E. R. Maurer of the University of Wisconsin, covering a series of tests just completed of the type "I" post.

REPORT OF TESTS ON TWENTY REINFORCED CONCRETE FENCE POSTS.

These posts were made of the "I" type described on pp. 801, 805, and were donated by the manufacturer to the University of Wisconsin for testing. The posts were made under the supervision of Mr. A. H. Miller, of the University, on "I" type molds. The unique feature of this machine consists in the "jogger," a device which oscillates the (vertical) form while the concrete is being poured, the purpose of the jogger being to insure solid posts. The reinforcements consist of five to six No. 8 steel wires tied together into a cylindrical bundle by 4 ties of No. 14 wire. The bundle is one inch less in diameter than the post. (The posts are circular in cross section, and the standard size is 7 ft. long and with end diameters 3¼ and 4½ in.). The longitudinal wires before being tied are crimped into a slightly wavy form, the waves being about one inch long and depth just perceptible. The yield point strength of this wire was about 100,000 lbs. per sq. in.

The cement used satisfied standard specifications. The sand was coarse bank and was screened to pass a ⅜-in. sieve; it then contained about 30 per cent. voids. Three mixes were used, approximately 1 to 2, 1 to 4 and 1 to 8. Cylindrical specimens 3 inches in diameter and 6 inches high of these mixes were tested at age 90 days with the following results:

Mix.	Ultimate Strength.	
1 to 2	2,580 lbs. per sq. in.	
	2,276 " " " "	
	2,310 " " " "	
	2,389 " " " "	average.
1 to 4	1,780 " " " "	
	1,630 " " " "	
	1,690 " " " "	
	1,700 " " " "	average.
1 to 8	770 " " " "	
	870 " " " "	
	836 " " " "	
	825 " " " "	average.

There were four lots of posts, five in each lot, as described in the adjoining table.

Lot.	Post Numbers.	Mix.	Reinforcement.
1	1-1, 1-2, 1-3, 1-4, 1-5	1 to 4	6 long. wires.
2	2-1, 2-2, 2-3, 2-4, 2-5	1 to 4	5 " "
3	3-1, 3-2, 3-3, 3-4, 3-5	1 to 8	5 " "
4	4-1, 4-2, 4-3, 4-4, 4-5	1 to 2	5 " "

Lots 1 and 2 were prepared to compare the five and the six wire reinforcements, and lots 2, 3 and 4 the three different mixes.

The posts were tested by Mr. S. E. Johnson of the University. The age of posts when tested was from 90 to 100 days. Three of each test were tested in cross bending with results as shown in Table I. The span

was 6 feet, supports 6 inches from the ends, and the load was applied 2 feet from the support near the large end of the post. Two of each lot were tested under impact load in a Hatt impact testing machine with the results as shown in Table II. Posts were supported as in the static tests and load was applied at same place. A 25-pound tup was used; initial drop of 5 inches, each succeeding drop was one inch higher than the preceding. Each test was stopped when the post failed to spring back or recover at all.

TABLE I.—CROSS BENDING TESTS OF REINFORCED CONCRETE FENCE POSTS.

Post No.	Mixture.[1]	Reinforcement.	Dia. of Post Under Load, Inches.	Maximum Deflection Under Load, Inches.	Maximum Load, Pounds	Average Load, Pounds.	Failure
1-1	1:4	6 wire	4.20	0.76	800		Tensile.
1-2	1:4	6 wire	4.22	1.06	1,250		Tens'le.
1-3	1:4	6 wire	4.30	0.89	830	960	Tensile.
2-1	1:4	5 wire	4.15	1.05	800		Compressive.
2-2	1:4	5 wire	4.15	0.90	760		Compressive.
2-3	1:4	5 wire	4.21	0.80	700	753	Compressive.
3-1	1:8	5 wire	4.19	0.97	640		Compressive.
3-2	1:8	5 wire	4.16	1.00	680		Compressive.
3-3	1:8	5 wire	4.41	1.07	660	660	Compressive.
4-1	1:2	5 wire	4.15	1.23	1,080		Tensile.
4-2	1:2	5 wire	4.15	1.05	970		Compressive.
4-3	1:2	5 wire	4.20	1.07	1,000	1,016	Compressive.

[1]These proportions are approximate.

TABLE II.—IMPACT TESTS OF REINFORCED CONCRETE FENCE POSTS.

No.	Mixture.[1]	Reinforcement.	Dia. of Post Under Load, Inches.	Total Work Done by Tup., in.-lbs.	Failure.[2]
1-4	1:4	6 wire	4.12	19,800	1
1-5	1:4	6 wire	4.22	11,800	1
2-4	1:4	5 wire	4.20	10,000	1
2-5	1:4	5 wire	4.35	12,150	2
3-4	1:8	5 wire	4.15	2,800	2
3-5	1:8	5 wire	4.50	4,050	2
4-4	1:2	5 wire	4.15	11,050	3
4-5	1:2	5 wire	4.36	9,000	4

[1]These proportions are approximate.

[2]Failure—

1 compression and shattering.

2 broke by shattering of concrete both under load and near small end.

3 tensile failure.

4 tensile failure, but concrete shattered somewhat before failure.

PROPORTIONING OF MATERIALS.

In reviewing the methods employed by the various manufacturers, also railroad companies, who have given this subject careful investigation, we find that they accord very closely with practices recommended

by the United States Department of Agriculture in Bulletin 403, and we, therefore, present certain extracts from that bulletin with some additional notes.

On account of the variations in the size of the sand grains and in the unfilled spaces between the particles of sand, stone and gravel, the quantities of concrete made, according to certain proportions may vary. For the same reasons the quantity of water may or may not be sufficient to make the concrete wet enough. Such matters, with the experience gained through making a few batches, may be easily adjusted. Water should always be measured by the bucket to have uniform results.

Different pockets of sand and gravel and different crusher-run rock vary in size and consequently in the unfilled spaces or voids between the grains or pieces. This variation, in theory, calls for varying quantities of cement, but the methods of determining the exact amount of these unfilled spaces are so complicated and so open to mistakes that with cement at its present price it is cheapest in the long run to adopt proportions or mixtures, which are rich enough to guarantee a well-made strong post. If unscreened bank run gravel is decided upon it should be used in the proportion of one part of cement to four parts of gravel. For crushed rock or screened gravel (which is much better than bank run gravel) the concrete should be used in the proportion of one part of cement, two parts sand and four parts of rock or gravel. Also one part cement to four parts chats makes good concrete.

All measurements should be made with the material poured loosely into the measuring box and the box when full should be leveled smooth.

The amount of moisture in sand, gravel and stone varies so much with weather conditions that the quantity of water for a cubic foot of concrete cannot be fixed exactly. During the mixing of the cement with the sand and rock sufficient water should be used for the concrete to be wet enough when the mixing is complete to tremble under a blow from the shovel. This amount of water causes a rich mortar to flow to the outside of the post and insures a smooth finish.

Bulletin No. 384 of the United States Department of Agriculture affirms that experiments conducted at the Colorado Experiment Station show that poured posts were a little over 25 per cent. stronger than tamped posts of the same size, mixture and reinforcement.

MIXING CRUSHED ROCK OR SCREENED GRAVEL.

In general, where crushed rock or screened gravel is used, the full amount of sand is spread out upon the board and upon it the necessary cement is evenly distributed. The whole is turned dry until the cement no longer shows in streaks, and the color of the batch is uniform. The mixture is then spread out flat, just as the sand was, and upon it the crushed rock or screened gravel is distributed evenly. Three-fourths of the water required is added and the mixing is continued. In dry hot weather it is a good plan to throw water on the pile of crushed rock before mixing.

OILING THE MOLDS.

Concrete has a tendency to stick to either steel or wood. In order to yield a smooth finish to the post, it is customary to give the inside of the molds a coating of oil. Soft soap or crude oils used sparingly serve the purpose well. Too much oil will destroy the setting qualities of the cement and will give a face roughened with pockmarks. A small amount of oil, poured into a pail of water and applied with a mop or stiff broom in scrubbing out the molds after they have been used five or ten times, or as often as necessary, will prevent the concrete from sticking.

MOLDING.

After the molds, which, as a rule, lie flat, but not always so, have been oiled or soaked, the concrete should be placed in them at once. If for any reason the concrete stands thirty minutes after mixing, it should be thrown away and a new batch mixed, for cement, if it has once partially set, makes weak, dangerous concrete, even though it is retempered by turning or adding water. If wooden molds are used, they should be well soaked in water so that the concrete post will not cause them to swell and thus crack the post. The wind, the hot sunshine and the frost are destructive to concrete; and while it is an easy matter to protect the post from the first two agencies, it is best to do no concrete work when the thermometer is below the freezing point, unless inside a building.

REINFORCEMENT.

Reinforcing should be placed near the outside wall, where it is reasonable to expect that cracks will open. For reinforcement, metal slightly rusted is as good as metal that is not rusted, if not better. In placing the reinforcing rods in position it is a wise precaution to bend them back at the ends. This takes only a little more time, but, if it is done, the reinforcement must be 2 in. longer to allow the metal to be turned back 1 in. at each end of the post. New barbed wire should not be purchased for reinforcement, for while it costs more than plain reinforcement, the bond between it and the concrete is no stronger than between smooth wire and concrete. The danger section, or the point where posts are liable to break, is at the surface of the ground. For fences for lots and other places where posts may be subject to rubbing and crowding, short extra reinforcing pieces 2 ft. long are sometimes placed in the post to lap this danger section. The corner of triangular-shaped posts, which is not nearest the fence wire should, in theory, have heavier reinforcement than either of the other corners. If rods three-sixteenths of an inch in diameter, No. 8 wire, or two twisted No. 12 wires, are used in the other corners, a rod one-fourth of an inch in diameter, or two or three twisted No. 12 wires, should be placed in the threatened corner.

CURING.

It is a great mistake to believe that, when the molding is done, a concrete post is finished. The quality of the post must be determined

by curing. The green post should be left in the mold until thoroughly hardened; that is, usually for two or three days.

During the first two days of the life of a post it must be kept wet and covered with canvas, burlap, carpet, or any clean material. Sand will serve after the concrete has become hard, but manure will stain green concrete and otherwise affect it. The sprinkling should be continued up to the eighth day. After the tenth day, if the space is needed, the post may, with care, be placed on end in the same manner that wooden fence rails were formerly piled. A drop of only 6 in. often breaks a green post. The jar in hauling to the field over rough, frozen roads or in a wagon bed with a very uneven bottom has seriously injured posts which were not well seasoned. Concrete posts gain rapidly in strength for the period of one year; they should, therefore, be made as long as possible before it is necessary to set them in the fence. No post should be used until it is at least 3 months old, and, to meet any contingency, a supply of well-seasoned posts should be kept on hand.

METHODS OF ATTACHING WIRE.

There are numerous methods of attaching wire fencing to concrete posts. Some makers place staples or wire loops in the green concrete; others make holes in the posts. The former method is not desirable, because the fastener cannot be located exactly where the wire of the fencing will come when the post is set in the ground; then, too, the fastener will eventually rust or break off and will thus injure the looks of the post. On the other hand, holes through the posts weaken them and therefore this method is, in general, unsatisfactory.

The simplest, easiest and cheapest way of fastening a wire fence to a concrete post is by encircling the post with a wire one size less than the corresponding wire in the fence proper, and by twisting this wire around the strand of the fence. This is done in two ways. The fastening wire is placed around the post, twisted upon itself and then to the fence wire; or one end of the fastening wire is twisted around the fence wire, and the free end is then carried around the post and twisted on the other side to the same wire. The latter method is known as "the Western Union twist." Either plan is good, but care must be taken to draw the fastening wire tight, or else stock trying to get through the fence may raise or crush down the fencing with their heads. If any trouble is experienced, the post should be roughened at the fastening point with a cold chisel.

Expansion and contraction of the fence, due to heat and cold, are cared for by the tension curves of "kinks" in the woven wire fencing, and no fear may be felt in drawing the fastening wires as tight as necessary. Wooden nailing strips should never be embedded in the posts, for moisture will swell the wood and crack the concrete.

TAPERED POSTS.

In the early stages of concrete post making it was the opinion of some, and yet remains so, that posts need not be tapered from base to top, but from the experience and testimony of those who have had a large practical experience in the matter, it has now been adopted as almost unanimous judgment that taper is necessary for many good and essential reasons.

It has been definitely demonstrated that it prevents heaving in winter, almost entirely if not absolutely. A fence post acts as a cantilever and the post is therefore largest toward the ground line, where it is the most severely stressed. It also reduces the amount of concrete required, lessening the quantity toward top of post where the full section, as at the base, is not required. The tapered post lends itself most naturally to the fastening of the fencing wire by means of the loop around the post with the Western Union twist; the taper prevents displacement of the loop.

CONCLUSIONS.

(1) Concrete posts are practical, economical and a suitable substitute for wood.

(2) Reinforcement should be placed as near to surface of post as possible; ½ in. from surface is best location.

(3) Post should taper from base to top.

(4) Post should not be less than 5½ in. at base and 4 in. at top.

(5) Concrete mixture should consist of one part cement to four of run of pit gravel; or one part cement, two parts sand and four parts crushed rock or screened gravel. Gravel or crushed rock not to be smaller than ¼ in. in size, nor larger than ½ in. Concrete should be of a quaking consistency.

(6) Molds should have a jogger or vibratory motion while concrete is being introduced to compact it and smooth up surface of post.

(7) Posts should not be made out of doors in freezing weather. They should not be exposed to sun, and should be sprinkled with water the first eight or ten days after being made to aid curing.

(8) Molds should be carefully oiled or soaped to provide a smooth finish and to prevent concrete sticking to mold.

(9) Posts should be cured for not less than 90 days before being set or shipped.

(10) Posts should be carefully handled and be packed in straw, sawdust or other suitable material for shipment.

RECOMMENDATIONS.

(1) We recommend the adoption of Conclusions 1 to 10 relative to concrete fence posts.

(2) We recommend that the foregoing conclusions be substituted for those in the 1911 Manual of Recommended Practice, page 210, upon the subject of concrete fence posts.

(3) We recommend to the Board of Direction that the Committee be directed to endeavor to have a series of tests conducted to determine the comparative strengths of the different forms of concrete fence posts and method of reinforcing, with a view to ascertaining the most suitable form. These tests to be performed, if possible, at one or more of the university or government laboratories.

(2) TRACK CONSTRUCTION AND FLANGEWAYS AT PAVED STREET CROSSINGS AND IN PAVED STREETS.

This subject has been under consideration for several years past, and your Committee has studied the practice in European countries as well as our own. It would appear as if the street and interurban rail lines have reached a higher state of development in this respect, both at home and abroad, than the steam lines. It is but natural that it should have been so, because of the greater extent to which they have been confronted with the problem.

It is probable that the most advanced type of construction will suggest and determine the best design for steam road work. They have been in such intimate contact with the difficulties encountered in track construction in municipalities, where the requirements for street paving were very rigid, that they have now achieved a type of construction that is giving most satisfactory results for their kind of traffic. We submit below brief comments upon important features of such track construction.

DRAINAGE.

The feature of good drainage, so essential to first class track construction, appears to have received abundant attention from street railway lines, and more than steam roads seem to have given it.

If the track superstructure is built on a concrete bed, the infiltration of water, which lies about the concrete, soon causes it to disintegrate under the constant impact of wheels passing over it, particularly at the rail joints, and soon reduces the concrete at such points to the consistency of mud, making track renewal soon necessary. If on the other hand ballast alone is used for the substructure of track, the natural bed beneath it soon becomes saturated and soft, and the resulting impairment of the track is inevitable. Drainage, therefore, is imperative. While satisfactory drainage provisions are necessary in any part of track construction, there is a conspicuous obligation to provide it at road, street crossings and through paved streets.

Each situation presents a separate problem, which will have to be solved to meet the conditions of the case; therefore, no definite recommendations can be made to cover the general proposition. It is sufficient to say that this feature of each piece of construction should receive careful and adequate treatment or the entire piece of work will prove a failure.

PAVING.

In both this and foreign countries, asphalt, bitulithic, wood block, brick, granite and trap rock paving have been tried. It has been exceedingly difficult to keep the paving along the rails in good condition where asphalt, asphalt blocks or bitulithic was used. In most cases where tried, these materials were removed from between the tracks, and for a distance of 2 ft. outside of rails, and replaced with wood or stone blocks. This has not only resulted in economy, but has also reduced the long interruptions to traffic due to the frequent repairs.

The El Paso & Southwestern System had an experience similar to this and states that:

"Laying the wearing surface of the bitulithic pavement directly against the rails was considered an experiment, and it was hoped that it might stand up against the rail. They have been disappointed in this and find that the bitulithic breaks and crumbles to an injurious extent at its contact with the rail. They have adopted the plan of laying three lines of vitrified paving brick against the rail, and so far this indicates a decided improvement. Even the street railway lines of the city have finally come to these three lines of paving brick against the rail as their standard construction."

The substance of our investigations would seem to indicate that granite or trap rock specification blocks make the most suitable material for this purpose.

SUBSTRUCTURE.

It seems from plans sent us to have been accepted, as a matter of fact, beyond the pale of argument, by most of the steam and street railway lines, that a concrete bed of thickness varying from 4 in. to 12 in. is the proper form of construction for the track substructure. Your Committee, however, believes that this is not conclusive and that it is still open to question, particularly in the case of steam roads with extremely heavy cars and heavy axle loads of motive power, whether a concrete base will not have a train of evils to follow in its course, even more serious than those to be met with in using a foundation of hard rock ballast, or other suitable material, with proper drainage provisions. This view is supported by some prominent authorities, and actual experience. We quote from an article appearing in Engineering News of May 23, 1912. The statement was an extract from papers prepared for the International Tramways Congress by Charles Rochat, of the Geneva Electric Railway Co., and A. Busse, Chief Engineer of the Great Tramways Company of Berlin.

"The substructure for street railway track may be either elastic or rigid. For the former, the most general plan is to use a bed of broken stone 6 inches to 10 inches thick and finished to the curved contour of the street, on which is a layer of ballast 3 inches to 4 inches thick. This method permits the infiltration and escape of surface water. It is employed with success when the street is macadamized or paved with stone. The rigid substructure has a base of concrete which either forms longitudinals under the rails or extends the full width of the street. Mr. Rochat considers that this gives a hard riding track and is open to the

objection of not being permeable. As the connection between the rails and the paving cannot be maintained watertight, water will enter and will eventually cause disintegration of the concrete. This type of construction is employed nearly exclusively for streets having asphalt or wood block paving. Engineers have tried to find a system combining a good relation of the track to the paving with facility for renewing rails, but thus far without success. Experiments have been made with blocks of reinforced concrete placed under the rails, partly to secure a good relation between the track and the concrete foundation of the street and partly to permit rapid laying and ready renewal of the rails, while limiting the width of the trench or cut to the minimum.

"At Geneva the rails are placed on hollow beams of reinforced concrete, which rest on the foundation concrete and provide for drainage along the rails. All of the plans thus far tried are based on the fact that the loosening of the rails embedded in the concrete may be prevented, or at least reduced, when the rails are supported on iron plates, chairs, wood or reinforced concrete blocks, ties or other devices, and when they are anchored with these supports in the concrete. In these systems where the ties are embedded in the concrete, great difficulty will be experienced when it becomes necessary to readjust rails and ties which will become loose, as this will necessitate breaking up and relaying the concrete base, and make the job very costly."

Furthermore, Mr. W. J. Boucher, in a recent discussion of Modern Street Railway Track Construction, says that:

"In the Loop Section of Chicago, where car, vehicle and pedestrian traffic is very heavy and congested, and where the necessary time cannot be given for concrete to set properly, and also for the reason that the streets in this section are likely to be torn up frequently for conduit, water pipe, or sewer work, or subway construction, the subgrade is rolled and on it is placed 1½ or 2 inch broken stone. This stone is well tamped, on it is laid wooden ties, 2 ft. from center to center, and the usual track structure is built."

It is necessary to say, however, that Mr. Boucher precedes this paragraph with the statement that the standard form of construction for all new work in all parts of the city, outside of the loop, is that with a concrete base for ties to rest upon.

The reasons set forth, however, for the rock ballast foundation in the loop section of Chicago are, in the opinion of your Committee, important considerations to be taken cognizance of in determining the proper form of construction through paved streets for steam roads.

It is to be observed that where ties rest directly on a concrete base, the bearing points at the joints are very rigid, causing the rail ends to hammer and soon become deformed. Water settling on the concrete bed at such points aggravates and hastens this condition. The adjacent rails themselves at a joint may vary by as much as 3-64 in. (the allowable limit), which is another condition that may lead to destruction of the rail and concrete beneath, from wheels pounding, where a certain amount of elasticity is absent. This state of affairs is readily noticeable in all street railway construction, regardless of how thorough the work was done originally. The service to be rendered by track under street railway traffic is not comparable to that needed under steam railway traffic. It is suggested that 60 ft. rails should be laid through road cross-

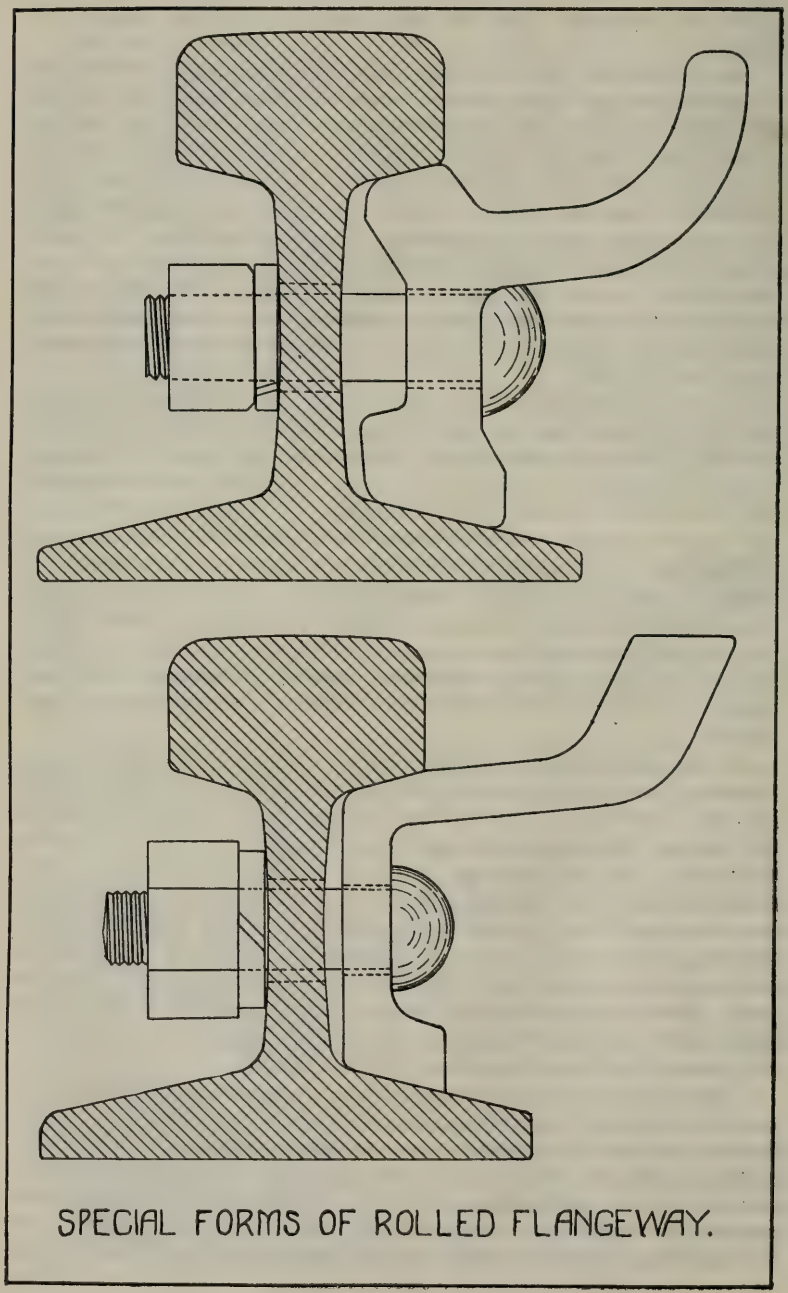
ings and paved streets to reduce the number of joints, the weakest part of the track structure. The East Paris line in France uses rails 78½ ft. long.

It is doubtless true that there may be certain particular locations where the subgrade is of such an infirm character that a bed of concrete will have to be laid in order to properly support the track, but even in such cases a cushion of ballast should be interposed between the concrete and bottom of tie. In the event that the track is in need of any resurfacing when laid directly on concrete, repairs are practically impossible, and entire renewal is necessary to improve conditions. It would seem to be far more preferable to adopt such a form of construction that light repairs, or even rail renewal, could be made at any time without an exorbitant expenditure. Track conditions under steam traffic necessarily must be maintained in a higher state of perfection than under street railway traffic.

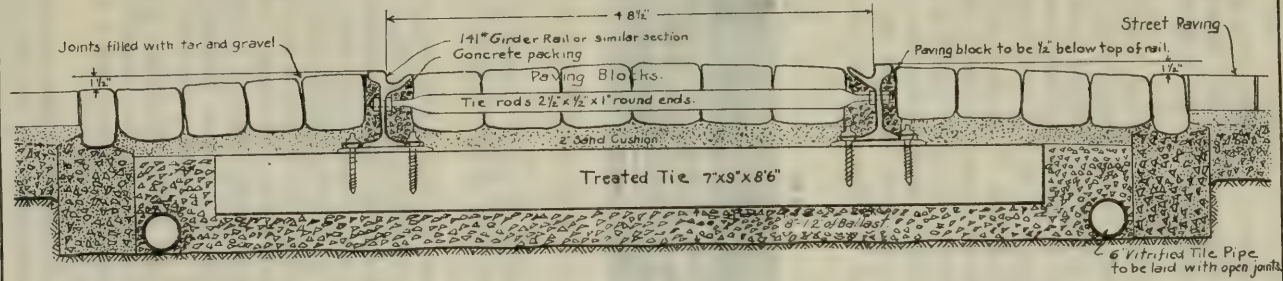
In a consideration of the various types of construction thus far tried, it is thought that the same design should be used at paved street crossings as through paved streets. The 141-lb., 9-in. girder rail appears to meet the general conditions of each case in the most satisfactory manner. It combines a proper form of flangeway for wheels, with the necessary flare to prevent horses catching the toe pieces of their shoes and holding them fast, together with the required depth for any character of paving. It will not permit of widening gage on curves, however. Ordinary tee rails (on chairs of various designs if necessary to obtain depth for paving), have been used; a special rolled form of flangeway or an old rail laid on its side for flangeway opening is frequently employed, usually the latter, but this cannot be considered as the best form of construction.

In previous Committee reports upon the subject of the best form of flangeway, the idea of a special rolled filler to provide flangeway opening has been referred to. This feature has been given some study and we find two or three roads using such an arrangement. It is our opinion that such a form of flangeway is suited to road crossing construction where paving is not required, but is not well adapted to street crossings where rigid laws are in effect in regard to paving requirements, or through paved streets. The steel companies can roll these special forms, but they are very expensive because of the little tonnage that would be used. They are not mill stock, because a different section is needed for each weight of rail, and because of frequent changes in rail section. We present hereafter two outlines of these designs.

The 9-in. girder rail can be very readily compromised to the ordinary tee rail with which the track is generally laid on each side of the crossing or at the end of the paved street. It is not the intention of the Committee to state that there are not other styles of construction that will give, or do give, good results; nor is it of the opinion that a more permanent form will not be devised in the future, but it believes that for the amount of money expended, that the design submitted, already tried



SPECIAL FORMS OF ROLLED FLANGEWAY.


8½"
Joints filled with tar and gravel
141# Girder Rail or similar section
Concrete packing
Paving Blocks.
Tie rods 2½" x ½" x 1" round ends.
2" Sand Cushion
Treated Tie 7"x9"x8'6"
8-12 of Ballast
Street Paving
Paving block to be ½" below top of rail.
1½"
1½"
6" Vitrified Tile Pipe to be laid with open joints

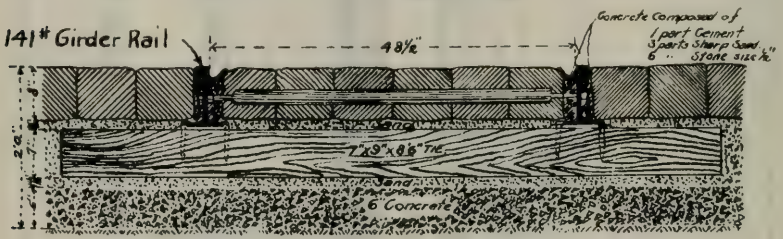
SECTION OF TRACK CONSTRUCTION

AT

PAVED STREET CROSSINGS AND THROUGH PAVED STREETS.

out under heavy service, will be best adapted to meet the most general requirements from the standpoint of durability, high standard and economy of maintenance. Simplicity of design and fewness of parts in any form of construction invariably leads to the achievement of the best results.

In Delaware avenue, Philadelphia, between Vine and South streets, the three track line, used jointly by the Pennsylvania, the Philadelphia & Reading and the Belt Line Railroad, is reported to be laid with 141-lb., 9-in. girder rail. The traffic is exclusively freight and is moved at a slow speed. A bed of concrete 6 in. thick is laid on the subgrade of the street and on this is a layer of sand 1½ in. thick in which the ties are bedded. Eight and one-half inches more of sand is then put in so that sand is 1½ in. above top of tie. The granite paving stones, 8 in. deep, are laid on the sand and grouted with tar and gravel. The ties are 7 in. thick by 9 in. wide and 8 ft. 6 in. long. The rails are laid on them with 6-in. by 11-in. tie plates, 15-16 in. thick. Tie rods are spaced 5 ft. 6 in.



Track Construction, Delaware Avenue, Philadelphia, Pa.

apart, six rods to each rail length of 33 ft. Twelve 1-in. bolts are used in each joint, arranged in two rows of three each on each side of joint. Splice bars are 2 ft. 8 in. long.

The Delaware, Lackawanna & Western Railroad uses as their standard construction through paved streets the 141-lb., 9-in. girder section of rail, laid on standard ties, treated timber preferable. If ties are not treated, they then use white oak. Standard tie-plates and screw spikes are used. From 12 in. to 14 in. of ballast is placed on subgrade; on top of this it is filled with ¼-in. stone within one to two in. of paving line. This is covered with fine cracked stone screenings, dust or coarse sand and paved with paving block or brick—joints to be filled with a mastic of tar and gravel cement. They have in some instances utilized the same construction and concreted it in by pouring grout into the ballast, but found it to work a disadvantage, as the rail seemed to pound out badly, and it was difficult to make repairs. Ties also pounded to pieces. Some of the rock ballast construction without concrete was in service eight years and proved entirely satisfactory.

The New York Central & Hudson River Railroad has had considerable experience in this form of construction. It has been installed in Wash-

ington street, Syracuse, on the Terrace at Buffalo, on Factory street, Watertown, and at other points. The original construction in these streets was the ordinary T-rail type on rail chairs, but was superseded by the 141-lb. girder rail construction, which proved so much safer and more satisfactory. Their work at Syracuse was very successful and relieved them of a great deal of maintenance. When they started it was their purpose to install two ft. of stone ballast under the ties, but they found by disturbing the old bed they could not maintain smooth paving, so they only dug out the subgrade to a sufficient depth to build the new track and surfaced it with ¾-in. stone. Their construction in Watertown was identical with this except that, instead of the strip bars or plain plates ordinarily furnished with the 9-in. girder rail, they used 36-in. continuous angle bars and made a three-tie joint. They found that the ordinary strip bar was too weak for this special construction.

The cost of this style of construction approximates eight dollars per foot, no credit being allowed for old material removed.

CONCLUSIONS.

(1) Specifications for best form of track construction and flangeways at paved street crossings and in paved streets:

Treated ties should be used, laid on a bed of crushed rock, gravel or other suitable material, not less than 8 in. nor more than 12 in. in depth, placed in about 3-in. layers, each to be thoroughly rammed to compact it.

Vitrified tile drains not less than 6 in. in diameter, with open joints, leading to nearest point from which efficient drainage may be obtained, or with sufficient outlets to reach sewers or drainage basins, should be laid on either side of and between tracks, parallel with ballast line and outside of ties.

141-lb., 9-in. depth girder rail, or similar section, with suitable tie plates and screw spikes should be used. Track should be filled in with crushed rock, gravel or other suitable material, allowing for 2-in. cushion of sand under finished pavement.

Ballast should be thoroughly rammed as it is installed for paving foundation to settle it. Two in. of good sharp sand should be placed on top of ballast.

Paving must conform with municipal requirements, granite or trap rock blocks preferred. Hot tar and gravel should be poured into joints as a binder.

(2) The inclusion in the Manual of the accompanying plan.

RECOMMENDATIONS.

We recommend the adoption of Conclusions 1 and 2, Specifications and Plan of Best Form of Track Construction and Flangeways at Paved Street Crossings and in Paved Streets.

(3) CONTINUE THE INVESTIGATION OF WAYS AND MEANS FOR SECURING A PROPER QUALITY OF FENCE WIRE TO RESIST CORROSION AND SECURE DURABILITY.

Your Committee has been continuing its investigations into this subject during the past year and has endeavored to obtain all available information as to the most recent practice, but it is compelled to state that the developments have been very few. It has investigated several foreign operations in the hope that they would indicate progress in the matter, but thus far these operations have not been applied to any large extent in the manufacture of fencing wire.

It is the opinion of one of the large manufacturers that the most practical solution of the problem of securing greater durability is by what is known as the "special galvanizing" process. The fence is made from wiped wire which will withstand four one-minute immersions in the standard copper sulphate solution for both the horizontals and stays. It is claimed that such a wire should compare favorably with unwiped wire, which will pass the same test. The Committee thinks, however, that this is open to question, although we understand that large tonnages of this special galvanized wire is being supplied according to specifications of foreign railway companies.

It was our impression that the English railway companies were not satisfied with wire supplied by United States manufacturers and in taking the matter up with the latter we learn that one of them was compelled to install such machinery in England that the fabric might be made of English wire in order to satisfy the trade of the United Kingdom. It is stated that their galvanizing is greatly superior to that of this country and that it is very largely done by the cold process or what is termed over here "electro galvanizing." So far as can be learned, no machinery or process has been developed in this country for that purpose that has proven satisfactory.

It is claimed that during the past several years more attention has been given here to the proper cleaning of the zinc before it is introduced into the zinc bath, and likewise the spelter has been more carefully scrutinized. One of our Canadian railroads in its specifications calls for a superior galvanized stock, which is run without wiping and lifted from the spelter bath at an angle of about 90 deg., being drawn through a charcoal flux on top of the bath, instead of being pulled through asbestos wipers as in ordinary practice. This process permits the maximum amount of spelter to cool upon the wire and at the same time prevents it from gathering in globules on the bottom of the strand, distributing it evenly over the surface in a smooth, heavy coating. It is claimed that cracking or peeling of the coating in the process of fabrication is very infrequent.

We believe that the method of weaving the wire is one of supreme importance and that the brutal treatment that the wire receives during the course of weaving at some plants might be responsible for the quick deterioration of the wire. So far no satisfactory method has been de-

vised of galvanizing the fence fabric after it has been woven, although many attempts have been made, but the expense appears thus far to be practically prohibitive from a commercial standpoint.

It is open to doubt in our minds whether the asbestos process of wiping the wire is as productive of good results as that of the old form of charcoal wiping. The asbestos wipers cannot at all times be adjusted with care and accuracy, so that one strand may carry a fair coating, while another will be wiped so closely as to almost entirely denude the steel.

In taking the matter of fence fabrication up with an expert in wire making, he stated that there were two accepted methods of fabricating the wire fencing.

The ordinary and most generally used is the custom of selecting a very soft wire, as the cross wire, first winding it on a bobbin so that it can be handled properly in wrapping it about the line wire of the fence. This process is extremely hard on the galvanizing and there is practically no wire that will stand the treatment without showing material injury to the coating. A modification of this practice is to feed the cross wire in short lengths, and where the ends of the sections pass one another at the crossing of the line wire of the fencing, they are seized by a twister and wound together about the lateral strand.

The other method is that of applying a straight single piece cross bar the full width of the fabric and attaching it to the line wires by a separate and distinct section of wire known as a tie. This process undoubtedly results in the least injury to the wire used in the fabric, although it is impossible to get away from the wrapping of the ends about the selvage wires when using the straight stiff stay.

There is another process of electric welding, but it is an open question whether this does not change the structure of the steel and destroy the coating at the point of contact.

It seems to us as if the various methods of fabrication are open to further investigation. The important points for consideration in the discussion of the wire fencing problem are:

(1) Method of Fabrication.
(2) Quality of steel used.
(3) Character of and method of galvanizing.

It is interesting to note that your Committee came into possession of a piece of buck-thorn fencing wire which has been in place on the Philadelphia & Reading Railway, near Gettysburg, since 1884. Through the courtesy of Mr. A. S. Cushman, Director of the Institute of Industrial Research at Washington, D. C., we obtained an analysis of this wire, which was as follows:

Analysis of the Steel Tape.

Sulphur	.058
Phosphorus	.114
Carbon	.090
Manganese	.299
Copper	.056

The zinc coating on the steel tape amounted to 1.88 oz. per sq. ft., and the analysis of the coating was as follows:

Lead	.37 per cent.
Tin	Trace
Zinc	99.63 per cent.
Iron	Traces

Mr. Cushman, commenting upon this analysis, stated that the above is unusually heavy galvanizing and is seldom met with in the trade nowadays, and that he believed that the heavy galvanizing of pure zinc spelter to have been the prime cause of the very long life of this material. It is also to be noted that the analysis of the underlying metal indicated that it was a mild steel with the carbon very low. An analysis of other steel devices that had been in use for a great many years also indicated very low carbon, manganese and sulphur, with a similar tendency toward high phosphorus.

For instance, three iron links in a wonderful state of preservation, taken from the Newburyport, Mass., suspension bridge, built in 1809, showed in a recent analysis carbon ranging from .04 to .12 and barely a trace of manganese and sulphur. A further investigation of the character of the underlying steel would appear to be productive of some good results. In our 1911 report we referred to a test that was being conducted by a certain railroad, commenced on April 1,1909. We obtained an up-to-date report on this as of November 14, 1912, as follows:

Test A.—Galvanized after weaving: Is at this time found to be in perfect condition, with no indication of rust anywhere.

Test B.—Ordinary Dip Process: The corrosion in this fence has been rapid during the past year; the galvanized coating has entirely disappeared, and the entire section of fence covered by red rust, and the deterioration from corrosion very rapid.

Test C.—Special Galvanized: Found to be in excellent condition; no corrosion apparent.

Test D.—Sherardized: Shows corrosion in an advanced stage; the preventative of rust infusion has largely disappeared, and my conclusion is that this method of treating wire as a rust preventive has proven less satisfactory than any of the others. The advanced stage of corrosion in this fence is about the same as that of Test B. It may be said, however, that we have no means of knowing that our sample fence was sherardized in the best manner, as the best facilities for sherardizing could not be obtained at that time. It is possible, therefore, that more perfect sherardizing would give better results.

Compare this report with that in Vol. 13, page 901, 1912 Proceedings.

It must be said, however, in connection with Test D, that important developments have taken place during the past several years in this process, and it may be found by further research that it has considerable merit. We note by tabulated results of inspection of fence wire tests, Carnegie Technical Schools, Pittsburgh, Pa., fences erected in September, 1908, inspection made November 30, 1910, by Special Sub-Committee

of Committee A-5, American Society for Testing Materials, that the sherardized woven wire fence, tabulated as Field No. 1, Inspection No. 27, showed an efficiency of 96 per cent., standing very closely in merit to the unwiped wires and wire galvanized after weaving, which were at that time practically perfect. It is unfortunate that these tests at the Carnegie Technical School had to be discontinued, as we learn that the fences were removed or at least disarranged through the extension of the plant at that school.

Your Committee is not prepared at this time to offer any additional information on this subject, nor is it warranted in reaching any conclusions. It believes that it is incumbent upon the railroad companies, in the light of past experience and with the information that has been imparted from time to time by the Association, to pursue their own investigations, and that investigation of this subject by the Association should for the present be discontinued.

RECOMMENDATIONS.

(1) We recommend to the Board of Direction the discontinuance for the present of the instructions to investigate ways and means for securing a proper quality of fence wire to resist corrosion and secure durability.

(2) We recommend to the Board of Direction that they assign to the Committee the investigation of the various kinds of signs for railroad purposes as applicable to both employe and the public.

Respectfully submitted,

COMMITTEE ON SIGNS, FENCES AND CROSSINGS.

REPORT OF COMMITTEE VIII—ON MASONRY.

G. H. TINKER, *Chairman;*
ROBERT ARMOUR,
G. J. BELL,
C. W. BOYNTON,
T. L. CONDRON,
J. K. CONNER,
L. D. CREAR,
L. N. EDWARDS,
A. H. GRIFFITH,
G. W. HEGEL,
L. J. HOTCHKISS,
F. L. THOMPSON, *Vice-Chairman;*
RICHARD L. HUMPHREY,
W. H. PETERSEN,
PHILIP PETRI,
J. H. PRIOR,
F. E. SCHALL,
G. H. SCRIBNER, JR.,
A. N. TALBOT,
JOB TUTHILL,
J. J. YATES,
Committee.

To the Members of the American Railway Engineering Association:

The work assigned to the Masonry Committee by the Board of Direction was as follows:

(1) Report on waterproofing of masonry and bridge floors, including methods, cost and results, with definite recommendations.

(2) Report on the effect of concrete structures of rusting of the reinforcing material.

(3) Report on the principles of design of plain and reinforced concrete retaining walls, abutments and trestles.

The following committees were appointed on this work:

(A) To consider report on waterproofing, etc., as given in Item 1: F. E. Schall, Chairman; C. W. Boynton, J. K. Conner, L. D. Crear, L. N. Edwards, Philip Petri and J. J. Yates.

(B) To consider report on Item 2: C. W. Boynton, Chairman: Robert Armour, A. H. Griffith, G. W. Hegel, Richard L. Humphrey, W. H. Petersen and G. H. Scribner, Jr.

(C) To consider report on Item 3: L. J. Hotchkiss, Chairman: F. L. Thompson, G. J. Bell, T. L. Condron, J. H. Prior, A. N. Talbot and Job Tuthill.

In the spring it was necessary for the Chairman, Mr. Tinker, to relinquish the Chairmanship of the Committee temporarily and during this time the work was handled by the Vice-Chairman.

COMMITTEE MEETINGS.

A number of Committee metings were held by Sub-Committee A in connection with waterproofing, and as the subject is a large one in which materials and new methods are coming into use all the time, it has been found impossible to submit a satisfactory report for printing in the Proceedings at this time.

Sub-Committee B has held a number of meetings in regard to the effect on concrete structures of rusting of the reinforcing material, and a report of this Sub-Committee is attached hereto as Appendix A.

Sub-Committee C has done a great deal of work during the summer and fall on the principles of design of plain and reinforced concrete walls, abutments and trestles.

The Chairman of this Sub-Committee resigned and Mr. T. L. Condron consented to serve as Chairman of the Committee.

They have done a great deal of work in the way of investigation and gathering together the information as to the design of retaining walls, abutments and trestles. They also made some effort to get some money from the Board of Direction and individual subscriptions in order to make a test of a section of a large size retaining wall, but were unable to obtain the necessary money to make this test. It is hoped the Board of Direction will see their way clear to authorize this test this coming year. Other than this the Committee has no report to make this year.

JOINT COMMITTEE ON CONCRETE AND REINFORCED CONCRETE.

During 1912 the Joint Committee has revised its previous report, to which has been added some new matter and the whole brought up to date. The report will be available to the various societies represented, including the American Railway Engineering Association, in the near future. The American Society of Civil Engineers received and accepted this report on January 15, and continued the Committee.

JOINT COMMITTEE ON STANDARD SPECIFICATIONS FOR CEMENT.

During the year meetings of the Joint Committee on Standard Specifications for Cement were held in an effort to harmonize the differences betwen the American Society for Testing Materials and the Government Engineers, and acting upon a resolution, representatives from the American Society of Civil Engineers, the United States Government, and the Society for Testing Materials were requested to confer relative to these differences. This conference had its initial meeting October 24, 1912, organized, and has been carrying on such investigation work as may lead to an agreement on Uniform Methods of Tests and Standard Specifications for Cement.

Respectfully submitted,

COMMITTEE ON MASONRY.

Appendix A.

DISINTEGRATION OF CONCRETE AND CORROSION OF REINFORCING METAL.

Attention should be directed, in cases where disintegration of concrete and corrosion of reinforcing metal are under investigation, to the quality of the concrete, to the concrete materials, and to the workmanship before any conclusions can be drawn as to the effect upon good concrete of the deteriorating agencies present. In deciding upon preventive measures again due attention to materials and workmanship will usually prove to be the most effective.

The failures of concrete structures most commonly reported are those due to

(1) Faulty design, including details.
(2) Use of improper materials.
(3) Poor workmanship.
(4) Neglect of proper precautions in removing forms and applying loads and otherwise overstressing new concrete structures.

While the subject of failures due to these causes is not considered to be included under the Committee's assignment, they are sometimes wrongly supposed to be due to the disintegration of concrete.

Failure to properly provide for shrinkage of concrete due to hardening in air, and for expansion and contraction due to temperature changes, is a common cause of cracks which may lead to failures.

The requirements for good materials have been described in numerous texts, specifications and reports, together with the methods of determining whether or not the materials meet the requirements. However, the proper precautions are not usually observed in choosing materials, especially aggregates. Although good concrete can be made with crushed stone screenings as fine aggregate, the results of laboratory tests on this material are likely to be misleading, and tests on specimens made to reproduce as nearly as possible field conditions of mixing, placing and hardening are especially desirable when screenings are used.

To obtain good work, competent and ample supervision is necessary, and no expedient can be resorted to that lessens the requirements for workmanship. In practically all cases where failures have been investigated, it has been found that the workmanship could have been improved with profit.

Probably the most common cause of failures of concrete structures has been the premature removal of forms. It has been definitely established that low temperature retards the hardening of concrete, and in work done during cold weather, precautions should be taken accordingly.

CONCRETE IN SEA WATER.

Investigations concerning the effect of sea water on concrete immersed for periods up to fifty years or more; of the relative merits of standard Portland cement and Portland cement made with varying contents of SO_3, MgO, CaO, Fe_2O_3, Al_2O_3, SiO_2, etc., in resisting the disintegrating effect of sea water; of the effect of varying the proportions of cement in the mortar and concrete; of the addition of various finely ground materials to the cement after burning; of the relative durability of concrete cast in place as compared with concrete blocks allowed to harden before placing in the sea; and of the effect of various materials added to the concrete mixture to produce impermeability and consequent increased durability have been made in various European countries and in America.

Regarding the chemical composition of the cement, the following conclusions are presented.

Cement containing up to 2½ per cent. of SO_3 resists the action of sea water fully as well as cement with lower SO_3 content.*

While all the hydraulic cements now in use are liable to decomposition in sea water, Portland cement is the one to be preferred in every respect.†

High iron Portland cement and puzzolan cement have failed to show superiority over Standard Portland cement in resisting the disintegrating effect of sea water.‡

Regarding the effect of varying the proportions of cement in the mortar and concrete, in general the richer mixtures have been found to offer better resistance to the attack of sea water.¶ Proportions recommended for mortars are those with one part cement to one part of sand up to one part cement up to two parts sand.§ The bad condition of mortars leaner than the above after exposure in sea water, stands out prominently.‖ In the use of reinforced concrete for maritime works, it is advisable to employ larger proportions of cement than are usual for similar works in fresh water.**

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*The effect of SO_3 in Portland Cement. Special publication. Proceedings of Association of German Portland Cement Manufacturers, 1911.

†International Association for Testing Materials, 1912. "Action of Sea Water on Hydraulic Binding Media."

International Association for Testing Materials, 1912, "Action of Sea Water on Reinforced Concrete."

‡See Engineering News, September 7, 1911, editorial, "The Different Iron and Slag Cements;" also Engineering News, August 3, 1911, "Ferrite Cement and Ferro Portland Cement," E. C. Eckel; for definition of cements.

International Association for Testing Materials, 1912, "The State of Preservation of Test Blocks," by W. Czarnowski.

National Association of Cement Users, 1912, P. H. Bates, Bureau of Standards.

¶International Association for Testing Materials, 1912, "Action of Sea Water on Hydraulic Binding Media." Lombard and Deforge.

§Viennot quoted in paper by Lombard and Deforge, International Association for Testing Materials, 1912, "Action of Sea Water on Reinforced Concrete."

‖International Association for Testing Materials, 1912, "Action of Sea Water on Hydraulic Binding Media." Lombard and Deforge.

International Association for Testing Materials, 1909, "Cement in Sea Water." A. Poulsen.

**International Association for Testing Materials, 1912, "Action of Sea Water on Reinforced Concrete."

Concerning the addition of finely ground material to the cement after burning, it has been found that the addition of ground puzzolan or furnace slag to Portland cement increases the resistance of the resulting mortar or concrete to the disintegrating effect of sea water.

Regarding the use of any material added to the concrete mixture in small quantities in order to reduce permeability, no results of practical working tests have demonstrated the value of any material in reducing permeability.

Allowing the concrete to harden under favorable conditions before exposure to the action of sea water greatly increases its resistance to attack by the sea water and is recommended wherever possible.

When concrete is deposited under sea water such precautions should be observed as will prevent the washing of the cement from the mixture.* Forms should be so tight as to prevent the entrance of sea water after depositing the concrete in order that a smooth surface may be obtained sufficiently rich in cement to be impermeable after properly hardening, and with the forms removed.

Where the effect of sea water on concrete has been other than mechanical, it is believed that disintegration is caused by the substitution of MgO from the sea water in the place of the CaO of the cement, as well as to the decrease in the proportion of silica and the increase in SO_3.

The making of a dense, impermeable concrete by the use of a well graded aggregate, rich mixture, proper consistency, and good workmanship, and allowing the concrete to harden under favorable conditions before being exposed to the action of sea water, are generally conceded to be efficient means of satisfactorily insuring the preservation of concrete in maritime works.

CONCRETE SUBJECTED TO THE ACTION OF WATER CONTAINING ACIDS OR ALKALIES.

Investigations concerning the effect of ground waters which contain acids or alkalies on concrete drain tile, sewers, tunnel linings, etc., and of the effect of sewage on concrete used in sewers and disposal works, have disclosed several instances of apparent disintegration. The following points have been demonstrated in regard to the resistance of concrete to these agencies.

Drain tile which, due to the use of poor aggregates, improper methods of manufacture or the use of lean mixtures, are porous, may be affected by the soil acids found in some localities or when required to carry strong alkali seepage common in many irrigated sections of the western United States.

The aggregate should be composed of materials inert to the acids or alkalies present in the water. A chemical examination of the sand from country known to contain alkaline soils is to be recommended.

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*See American Railway Engineering Association, 1912, report of Masonry Committee, "Methods of Depositing Concrete Under Water."

Water containing substances known to react with the elements of the cement should be kept from coming in contact with concrete until the latter has thoroughly hardened.

Care should be taken to provide a smooth surface and sufficient slope to the extrados of the arch of tunnel linings and sewers when the ground water level lies below the tunnel grade to facilitate the flow of seepage water to the sides. It is believed that the back filling over the arch ring should consist of porous material such as coarse, crushed stone, for the same reason. It is also believed that side drains should be provided where necessary and connected with an under drain, which should be provided in all cases.

The alkalies which are most active in causing disintegration of concrete when allowed to penetrate into the interior of the mass are the sulphates of sodium, magnesium, and calcium.

The measures to be used in making concrete which is to be exposed to the action of these deteriorating agencies in order to prevent disintegration are the same as recommended for sea water construction. Impermeability is the prime requisite and the results of experiments and practical tests indicate that plain concrete, carefully prepared, is just as resistant, if not more so, than concrete mixed with foreign materials or special preparations.

Disintegration of concrete in sewers and sewage disposal works, whether due to the use of poor materials, poor workmanship, or insufficiently rich mixtures, has been found to take place above the normal surface of the liquid contained. The following explanation is advanced for this action.

Quantities of hydrogen sulfid are evolved from the sewage. This sulfid is produced in two ways: (a) By the bacterial decomposition of sulphur-containing-proteins and related compounds, and (b) the reduction of sulphates which are contained in unusual amounts in some water supplies. Of the two, the second seems to be the more important. The hydrogen sulfid which escapes as gas from the sewage is partially dissolved in the moisture on the under side of the roof and concrete walls. Here it is oxidized to sulphuric acid partly by atmospheric oxidation and partly by bacterial action. The sulphuric acid acts upon the calcium compounds in the concrete forming calcium sulphate and breaking down the concrete.*

DISINTEGRATION OF CINDER CONCRETE.

Cinders with much sulphur are likely to give unsatisfactory results in concrete, especially if there is much coke or porous material present. Such cinders may be improved if allowed to weather, with occasional washing until the ferrous iron and sulphur have been oxidized and bleached out.†

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*Bulletin No. 26, Engineering Experiment Station, Ames, Iowa.

†Journal of Industrial and Engineering Chemistry, June, 1912. "Some Observations on the Disintegration of Cinder Concrete," by George Borrowman.

Porous cinder concrete in roofing slabs exposed to the action of locomotive gases does not form an efficient protection for reinforcing metal, which has been found to corrode and cause the disintegration of the slab.*

Freshly made concrete surfaces in contact with smoke gases at temperatures below 45 degrees F. have failed to harden properly, and experiments indicate that under such conditions the cement is acted upon by some of the gases. It has therefore been recommended that when heating is done by means of open fires, higher temperatures should be maintained.†

EFFECT OF ELECTRIC CURRENTS.

Laboratory experiments furnish most of the information which exists concerning the effect of electrical currents on concrete and reinforcing metal. The discrepancy between the conditions in these experiments and field conditions seems to be greater than is the case in other laboratory tests on structural materials, and the information obtained up to this time is difficult of application to field conditions.

It has not been shown that the strength of plain concrete is affected by the passage of an electric current through it.

It is generally accepted that if an electric current passes into concrete through steel which is tightly embedded in it, the steel is corroded and the expansion of the metal, due to corrosion, disrupts the concrete. Corrosion takes place at the anode (pole from which current flows). The cathode is not affected by oxidation.

CORROSION OF REINFORCING METAL.

Results of experience up to date have shown no reason for changing the conclusions presented in the Progress Report of the Joint Committee on Concrete and Reinforced Concrete, 1908: "Tests and experience have proved that steel embedded in good concrete will not corrode, no matter whether located above or below fresh or sea water level. If the concrete is porous, so as to be readily permeable to water, the metal may be corroded in the presence of moisture."

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*Engineering Record, July 30, 1910. Replacing Concrete Roof Slab, La Salle Street Station.

†American Society for Testing Materials, Vol. 9. Alfred H. White, "Disintegration of Fresh Cement Floor Surfaces."

REPORT OF COMMITTEE VI—ON BUILDINGS.

MAURICE COBURN, *Chairman;*	M. A. LONG, *Vice-Chairman;*
G. W. ANDREWS,	W. H. FINLEY,
J. P. CANTY,	G. H. GILBERT,
O. P. CHAMBERLAIN,	A. T. HAWK,
D. R. COLLIN,	H. A. LLOYD,
C. G. DELO,	L. G. MORPHY,
W. T. DORRANCE,	C. W. RICHEY,
C. H. FAKE,	W. S. THOMPSON,
C. F. W. FELT,	*Committee.*

To the Members of the American Railway Engineering Association:

The Committee on Buildings has held two general meetings during the year; one at Chicago immediately after the convention and one at Pittsburgh in November. The Committee was divided into two parts; the Eastern section held several meetings at New York and the Western section held meetings at Chicago.

The following subjects were assigned to the Committee by the Board of Direction:

(1) Present principles covering the design of inbound and outbound freight houses.

(2) Report on recommended methods of heating, lighting and sanitary provisions for medium-sized stations.

(3) Complete report on roof coverings.

(4) Report on the advantages and disadvantages of various types of freight house floor construction.

Progress is reported on subject (1).

Reports on (3) and (4) are presented herewith.

No recommendations are made as to revision of the Manual.

(3) REPORT ON ROOFING.

The following report on roofing combines the matter presented in the reports of the two past years, with some corrections and some additions.

The Committee is of the opinion that much of this report on roofing should go into the Manual. We would like, if possible, to have this in the next edition. The report is too long to go over in detail at the convention, and members interested are asked to go over it carefully, and be prepared to discuss it at the convention, if they disagree in any parts.

In the revision, we are particularly indebted to Prof. A. L. Dean, of Yale University, for valuable criticism and information in connection with the bituminous materials.

THE BITUMINOUS ROOFING MATERIALS.

The bituminous roofing materials are varied and complex and what accurate knowledge there is about them is largely held by the experienced

manufacturers. This is gradually being disseminated and the intelligent purchaser every year is able to buy with more confidence.

There is yet much to be learned, and even if our report accomplished its aim of presenting accurately the present available knowledge of this subject, it would soon be out of date.

The bitumen substances are organic compounds, largely composed of many different hydrocarbons, with different chemical formulæ and widely-varying melting points. They vary so and the knowledge concerning them is so limited and new that considerable confusion exists in regard to nomenclature and classification. They are always accompanied by greater or less amounts of impurities, and are obtained either naturally or as the heavier distillates or residues of coal, petroleum or other organic substances. Their distinguishing characteristics are their elasticity and binding power or adhesiveness, their considerable immunity from action by water and their solubility in oils and certain other organic compounds.

In the commercial preparation of the different bitumens obtained from coal and petroleum, distillation is used to mechanically divide them into classes of compounds having similar physical qualities. When in this process sufficient heat is applied to cause a chemical breaking down of some of the hydrocarbons, the operation is termed cracking.

Asphalt.—The term asphalt is ordinarily considered as referring to bitumens found naturally in the solid state and will be so used in this discussion. These are obtained all over the world with widely-varying qualities. Mention will be made of those most important commercially in this country.

The asphalts are generally stable in the atmosphere. As found naturally, they are not commercially available, even after the impurities are removed, being too hard and brittle for most purposes. This is ordinarily remedied by softening or fluxing with various oils, an operation requiring skill. The character of the fluxes has a most important effect upon the finished product. Petroleum products are ordinarily depended on for this purpose. The fluxes should be sufficiently stable to insure against too rapid hardening of the fluxed asphalt. They should be free from deleterious constituents and should be of such a character that they will combine with the asphalt to be fluxed so as to make a homogeneous and perfect solution. Certain fluxes which work well with certain asphalts are not at all suitable for use with other asphalts. Tars are sometimes employed for fluxing purposes, but they do not mix easily with the asphalt. As asphaltic compounds age they tend to become brittle and hard, losing their elasticity and binding power. Poor fluxing hastens this process.

A single asphalt fluxed by a single oil is ordinarily an imperfect and unsatisfactory roofing material, the oil having a tendency to separate out and evaporate, leaving the remainder hard and brittle. The fiber of the rag felts ordinarily used in roofing work are supposed, by capillary action, to hasten this process with asphalts used as saturants. The successful asphaltic roofing compounds are ordinarily composed of several different materials.

Commercial refined asphalts, intelligently and honestly refined, should and do run very uniform. When they are compounded, however, brand names have very little significance and less value, and should not be taken in themselves as indicative of the character or value of the compound. Some types of asphaltic compounds properly prepared and used have qualities which make them almost indispensable for some classes of roofing.

The asphalt which has been most widely exploited in the United States is that which comes from the Island of Trinidad. This occurs in a large deposit and has the valuable feature of being unusually uniform in quality. As mined it contains large percentages of water and of mineral matter in a finely divided state. There are also some soluble salts present in small quantity, which possibly may help to explain the fact that it is acted upon by standing water, and is not suited for use in underground waterproofing and at points where it does not have a chance to dry out. This is not so serious a defect in a street pavement where the surface coating is made dense and where the pavement is covered by water for short periods only. Sunlight affects it somewhat, but it is not volatile in the atmosphere. Over a third of the refined product is mineral matter.

Bermudez asphalt comes from Venezuela, is not quite so uniform as the Trinidad and is softer than the other widely-known commercial solid asphalts. It contains but little mineral matter, but otherwise possesses many characteristics similar to those of the Trinidad.

In Colorado and Utah occur gilsonite and elaterite, which have some characteristics in common and which are often nearly pure bitumen. Gilsonite is hard and brittle, requiring considerable quantities of flux to make it available for use. It is not always uniform in its qualities. It is to some extent exported and is used for varnish. It is claimed as the base of many of the asphalt roofings, but is not a good saturant.

Elaterite occurs in Utah, in territory near where gilsonite is found, and has much the same appearance, but is found only in narrow veins. Its qualities are considerably different from those of gilsonite, said to be in part due to the presence of considerable sulphur. From it is made a high-priced product which is supposed to be especially valuable as a constituent of the protective coating of ready roofs. We are of the opinion that some products advertising elaterite contain it in only small quantities, if at all.

Grahamite or "Choctaw," which now comes from Oklahoma, is not much used for roofing. It does not dissolve readily in the ordinary fluxes and in its physical characteristics is more like soft coal. The original product was better. The original Grahamite is a deposit of asphalt in West Virginia, which looks somewhat like the Oklahoma Grahamite, but fluxes more readily and is a better material for roofing. Properly fluxed, it is elastic and durable.

Southern California has deposits of asphalt of excellent quality, but their cost of mining and the excellent character of the California

oil residuals has driven them out of use. When California asphalt is mentioned, the oil residuals are ordinarily referred to.

Rock Asphalt or Mastic Rock.—Sandstone saturated with bitumen is found naturally in various places in the country, principally in California. It is sometimes known as mastic rock, and is more valuable for paving and floors than for roofing or waterproofing, where it is rarely used. There is also bitumen saturated limestone, of which that found in Uvalde County, Texas, is an example.

Maltha.—Maltha, in this country found mainly in California, is a semi-liquid asphalt, containing light oils which tend to evaporate upon exposure to the atmosphere, leaving what is practically an asphalt. It grades into the California petroleum and the deposits are not extensive enough to be of importance commercially. There are underground deposits of this material so heavy that they cannot be pumped and for which no practicable scheme of extraction has been devised.

Petroleum Residuals.—The petroleums found in the United States vary in quality according to their location. Hubbard* divides the important deposits into six fields, as follows:

Appalachian—From western New York through western Pennsylvania, eastern Ohio, northwestern West Virginia into eastern Kentucky and Tennessee.

Lima—Indiana—Northwestern Ohio and eastern Indiana.

Illinois—Southeastern Illinois.

Mid-Continent—Southeastern Kansas, eastern Oklahoma and northern Texas.

Gulf—Louisiana and all of Texas except the northern portion.

California—Southern California.

The Pennsylvania oils are rich in the paraffines and in the lighter and more valuable illuminating oils and naphthas. Most of the California oils are practically free from paraffines and have comparatively small quantities of the illuminating oils. They are darker in color, have a greater specific gravity and have what is known as an asphaltic base. The oils found in the intermediate fields have qualities varying between the two extremes in the order named.

Eastern oils are largely made up of compounds of the paraffine series, varying in consistency from comparatively thin oil to hard scale paraffine. While most of the paraffine compounds are useless as binding materials, many of the fluid paraffines are excellent solvents for certain asphalts and are in every way suitable for use as a flux. In the early days of the asphalt industry almost all the pavements were laid with an asphalt cement in which the refined asphalt was fluxed with a residuum high in paraffine, and the fact that these pavements gave excellent results shows that reasonable quantities of even scale paraffine are not necessarily destructive to the value of asphalt cements. The state in which the paraffine exists in an asphalt cement, i. e., whether in com-

*Dust Preventives and Road Binders, Wiley & Sons, 1910.

plete solution or not, is of much more importance than the amount present so long as this is kept within reasonable limits.

The heavy residue from the distillation of the California oils is a substance with many of the desirable qualities of the best asphalts. The crude oil is distilled down to the required density and a product obtained with even and valuable qualities. Very large quantities of California oil asphalt have been used throughout the United States for paving and roofing purposes. Its use has not been at all confined to the Pacific Coast. It is probably true that more asphalt roofing felt has been saturated with California oil asphalt than with any other kind of asphalt. This oil asphalt when heated becomes very liquid at comparatively low temperatures, and, for this reason, is especially suitable for saturating felt.

The method of distillation of California oils profoundly modifies the character of the residual.

The heavy residuals of the Gulf, Mid-Continent and Illinois petroleums are used in large quantities as substitutes for asphalts, frequently under that name. They are ordinarily less expensive than the natural asphalts. As compared with the California residuals, they contain more paraffine, are lower in ductility and adhesiveness and, except that some of the residuals of the Texas oils are very stable, are in most ways inferior for roofing. Sometimes they are used as adulterants with better materials.

To make them more stable and less affected by heat and cold, air is blown through them while hot. This reduces their ductility and adhesiveness as well as their susceptibility to temperature changes. They can be made into a very uniform product of great value for many purposes, and it is the general belief that the better residual products result when the distillation is so conducted as to cause a minimum amount of cracking.

Their use has in the past been limited by patents, but the original ones have expired and the validity of others is now before the courts. They are not as good saturants as an untreated residual, but for the protective coating of ready roofings they have considerable value, as they are stable and are not readily affected by the heat of the sun. They are not selected for stone-surfaced roofings because of their lack of adhesiveness. Vulcanizing of the residual with sulphur produces results similar to the blowing with air.

THE TARS.

Coal Tar.—From the distillation of bituminous coal, either in a plant for the production of illuminating gas or in a by-product coke oven, the products may be roughly divided into four classes, the gas, the ammoniacal liquor, which is the scrubbing water with the materials which it has absorbed from the distillates and which it holds in solution, the coal tar, a heavy liquid containing the distillates insoluble in water which have settled away from the ammoniacal liquor, and the coke.

The coal tar contains some water, various impurities and free carbon which, after the water has been removed, is ordinarily from five to

thirty-five per cent. of the total. This is carbon formed by the cracking of the hydrocarbons and is in a very finely divided condition. The percentage varies with the method of manufacture. The distillates or bitumen are composed mainly of hydrocarbons which have widely varying melting points and degrees of volatility. These may be roughly classified into light oils, creosotes and pitches. The character of the tar varies with the coal used and the manner in which the process is carried on. The tar from each plant has its individual characteristics. The greater the heat, the more the hydrocarbons are cracked into their constituents and the greater the amount of free carbon and of gas found and the less the amount of coal tar. By carrying the process to its theoretical limit the final products of distillation would be gas and carbon.

The question of the relation between free carbon and coal tar is one of considerable importance. It is generally considered to be a valuable adjunct to roofing tars and pitches. Free carbon makes the material less affected by changes in temperature. Comparing two pitches of similar consistency at normal temperatures, the one having the greater amount of free carbon must have to neutralize it a greater per cent. of the lighter, more elastic and to some extent more volatile hydrocarbons and less of the heavy pitches. When it is cold the pitch is less brittle and when it is hot it does not flow so readily because of the carbon present. Thus a tar of given consistency may, notwithstanding the fact that it contains large quantities of an inert material, apparently have more life than another with less of the free carbon.

To determine the probable action of any tar or pitch under different temperatures its percentage of free carbon must be known as well as its melting point. The free carbon in moderate amounts does not interfere with the saturating power in felt.

When coal tar pitch is exposed to the weather there is found upon its surface a thin layer, hard and brittle, the residue after the drying out of the volatile oils. This acts as a sort of protective coating to what is underneath. As soon as it is disturbed, exposing fresh pitch, the process is repeated. High carbon tars seem to weather better than low carbon.

Water Gas Tars.—In making carburetted water gas, the procedure is as follows: Steam is blown through a bed of incandescent coal or coke, where it is broken up, forming blue water gas, which consists of about equal quantities of hydrogen and carbon monoxide. This gas, which has no illuminating value, is passed into a second chamber, which is filled with checker brick and which has been previously raised to a high temperature. Into this chamber is sprayed petroleum oil, which, by the intense heat, is broken down into permanent gas and a tar consisting, partly, of aromatic hydrocarbons similar to those occurring in coal tar. This permanent gas is of high illuminating value and imparts its luminosity to the blue water gas, while the tars drop out further on in the process of manufacture. It is from this tar that oil tar pitch and other products are obtained.

In the process which it undergoes the oil residues are so changed by the high heat as to lose many of their characteristics and to acquire some of those of the compounds found in coal tar. Compared with coal tar, its oils have less antiseptic properties. As obtained from the gas manufacturers it is thinner, containing more light oils, less of the pitches, and often more water. The oil tars are subject to considerable variation, depending upon the methods and materials used. They are distilled down and treated much as is coal tar and its pitch is very similar in appearance to that of coal tar.

Water gas tar contains some free carbon, but usually not over 2 per cent. Its pitch is not acted upon by water. There is a very general opinion among practical roofing men that the water gas tar products are less stable than the coal tar pitches, but we cannot find that there has been any accurate proof of this. Its small percentage of free carbon materially interferes with its value as a roofing pitch. It is said that carbon can be added, but we doubt the commercial practicability of such a scheme.

Oil tar decomposes more easily than coal tar. It often contains some paraffine, though ordinarily not in sufficient quantities to affect the product as compared with coal tar. The crude water gas tar is also much more affected by water and is capable to a considerable extent of forming an emulsion with it. Good coal tar is practically unaffected by water, and it deteriorates from the surface only.

Water gas is now made practically everywhere and ordinarily mixed with coal gas. In one large plant from the same amounts of gas the water gas produces about a third of the amount of tar that coal gas does. The coal gas, considering its by-products, is under favorable conditions the cheaper, but the water gas requires less of a plant and allows greater flexibility of operation. The prices of materials and the demand for coke affect the relative outputs. In the large plant previously spoken of the proportions of coal and water gas made vary between two and three of water gas to one of coal gas.

In the larger illuminating gas plants the two sorts of tar are generally separated, but in many of the smaller plants they are mixed together. There is no reason why they should not be kept separate except for the cost of separate receptacles. In this country the by-product oven and gas tars, both coal tar and water gas tars, are bought by a comparatively limited number of concerns, who closely guard their processes. They compound the different sorts possessing varying characteristics, endeavoring as far as possible with their supply and their desire for maximum profits to meet the needs and demands of the consumer. The consumer in his ignorance does not know what he is getting and probably usually does not know what he needs. The detection of oil tar in coal tar products is a difficult and uncertain matter, especially when it is under twenty-five per cent. of the total. We are not sure that it has been proven that a reasonable amount of water gas tar seriously injures a coal tar for roofing purposes, especially when used as a saturant, although it is generally in disfavor.

Not long since practically the only use of tar was for roofing and the entire supply came from the manufacture of illuminating gas from coal. The situation has been changed by the increasing supply from by-product ovens, by the manufacture of water gas in large quantities, by the great demand for creosote oils and other by-products, by the use of coal tar pitch for waterproofing masonry, by its use for briquetting coal slack and by its adoption for use as a road binder.

We would sum up the remarks on the bituminous materials as follows:

With skill in compounding, based on a thorough working knowledge of the materials used, asphaltic compounds can be prepared of natural asphalts and oil residuals with valuable qualities for many different roofing needs, whose durability under known conditions can be foretold with considerable accuracy. The same can be said, perhaps with more certainty as to results, of the different tars. Either can suffer from adulteration and poor preparation. Considering first-class materials the coal tar is cheaper, more easily affected by temperature changes and is not acted upon by water nor is it liable to internal changes.

From these compounds the only definite information that can be furnished by laboratory tests as to probable life and weathering properties is negative in its nature and quite inconclusive. Specifications to be enforced must include factory inspection and knowledge of materials used.

In order to meet the statements concerning the difficulties in getting, at the present time uniform straight run coal tar pitch of good quality, the leading manufacturer of coal tar is making arrangements with the Underwriters' Laboratories to make factory inspection of his labeled products. Preparations for this are being made in a thorough manner and competitors, to put their products in the same class, must also arrange for the same inspection. This, together with the specifications, enlarges considerably the possibility of being sure of getting good materials for a built-up coal tar roof.

FELTS.

The felts used with almost all bituminous roofings play a very essential part in the final product.

The desirable qualities of the felt vary with the saturating material to be used. With asphalt saturating power is the main desideratum. For coal tar, which under heat is much more liquid, this quality is not so necessary. All must be strong enough to avoid damage in handling before saturation. The strength of the finished product is due to a great extent to the saturation.

The felts are mainly made of rag stock, which is chiefly cotton rags. Notwithstanding the statements of many manufacturers, all-wool felt is never used for roofing, because of its expense and because it would be too soft and tender to work. A certain proportion of wool rags helps to make a felt which is open and spongy with considerable saturating power. Felts for saturation by asphalt rarely contain more than 25 per

cent. of wool. As ordinarily used the term wool felt applies to a soft open felt with very little wool in it.

Sometimes paper stock, which is ordinarily wood pulp, though it may contain an appreciable percentage of straw, is used in small quantities if the felt is getting too soft. It has practically no saturating power, but it can add to the cheapness of the material. If used in anything over two or three per cent., it is an adulterant to cheapen the product when it is made to sell to roofing manufacturers, or to make it less absorbent, as in the case of slaters' felt or hard felt for making up into two and three ply coal tar felt.

The felt materials ordinarily come to the factory in large bales, already sorted with fair accuracy, and are bought according to different grades. These are used together in varying proportions to get different results and to meet variations in the materials. But little sorting is done at the plant except to watch for specially undesirable constituents.

The methods of manufacture have a considerable effect on the quality of the material. The felt must be well beaten to avoid large lumps, which are sources of weakness. The felt is made on a machine similar to that used for making ordinary paper and variations in its operation determine the quality of the finished products.

The dry felts are sold by weight. The standard is the amount which would lay 480 sq. ft. If a felt weighs 28 lbs. to 480 sq. ft., it is known as No. 28. For this reason felts sometimes have their weight increased by the addition of a mineral filler. This is nothing more than an adulterant which interferes with the saturating power. Some specifications which require a certain weight of felt get around such adulteration by requiring that the ash in the unsaturated felt must not exceed 5 per cent.

Felts of asbestos are used in one or two roofings. These are poor saturants and are more in the nature of protection to the asphalts. They will not burn or decay.

Jute woven in the form of burlap or canvas is used in some roofings to add strength. Its value is debatable. It is not a saturant like the felts and its fibers are not so thoroughly protected, making it liable on exposure to rot. Burlap decays much more readily than the average cotton felt.

The main use of tar for roofing has been in the construction of built-up roofs, where layers of felt saturated with tar are nailed down and by the use of a tar pitch protected and cemented together.

The following specification accompanied by the necessary diagrams give what is considered as good practice in the construction of a flat built-up roofing on wooden sheathing.

SPECIFICATION FOR FELT, PITCH AND GRAVEL OR SLAG ROOFING OVER BOARDS.

Incline.

This specification should not be used where roof incline exceeds three (3) in. to one foot. For steeper inclines modified specifications are required.

SPECIFICATION.

Roofing.

First, lay one (1) thickness of sheathing paper, or unsaturated felt, weighing not less than five (5) lbs. per hundred (100) sq. ft., lapping the sheets at least one (1) in.

Second, lay two (2) plies of tarred felt, weighing fourteen (14) to sixteen (16) lbs. per hundred (100) sq. ft., lapping each sheet seventeen (17) in. over the preceding one, and nail as often as is necessary to hold in place until remaining felt is laid.

Third, coat the entire surface uniformly with straight run coal tar pitch.

Fourth, lay three (3) plies of tarred felt, lapping each sheet twenty-two (22) in. over the preceding one, mopping with pitch the full twenty-two (22) in. on each sheet, so that in no place shall felt touch felt. Such nailing as is necessary shall be done so that all nails will be covered by not less than two (2) plies of felt.

Fifth, spread over the entire surface a uniform coating of pitch, into which, while hot, imbed not less than four hundred (400) lbs. of gravel, or three hundred (300) lbs. of slag, to each one hundred (100) sq. ft. The gravel, or slag, shall be from one-quarter (¼) to five-eighths (⅝) in. in size, dry and free from dirt.

Flashing.

Flashings shall be constructed as shown in detailed drawings.

Labels.

All felt and pitch shall bear the manufacturer's label.

Inspection.

The roof may be inspected before the gravel or slag is applied by cutting a slit not less than three (3) ft. long at right angles to the way the felt is laid.

N. B.—To comply with the above specifications, the material necessary for each one hundred (100) sq. ft. of roof is approximately as follows: 100 sq. ft. sheathing paper, 80 to 90 lbs. tarred felt, 120 to 160 lbs. straight run coal tar pitch, 400 lbs. gravel, or 300 lbs. slag.

In estimating felt, the average weight is practically fifteen (15) lbs. per one hundred (100) sq. ft., and about ten (10) per cent. extra is required for laps.

In estimating pitch, the weather conditions and expertness of the workmen will affect the amount necessary for the moppings, and to properly bed gravel or slag.

The sheathing paper or unsaturated felt is placed on the bottom next to the roof boards, mainly to keep any pitch which might penetrate the two-ply felt above it from cementing the roofing to the sheathing. It also is of value in preventing the drying out of the roof through open joints from below.

To combat severe conditions encountered like those at locomotive engine houses, instead of the dry sheet, an asphalt or oil-saturated felt is sometimes used. This does not so readily deteriorate. One roofer uses for this purpose asphalt asbestos sheets.

The saturated felts should be nailed where there is any chance of disturbance of the roof from underneath by wind and also enough to hold it in place while laying. The practice in regard to nailing varies in different parts of the country, but the fewer nails the better so long as the roof is held in place.

For a concrete roof the practice is similar except that a dry sheet is not necessary, there is no nailing and the concrete is first coated with pitch. Special care should be taken in regard to flashing and to prevent the roofing from being loosened at the edges either by wind or fire. Most leaks occur around flashings and openings.

The two layers of saturated felt first laid are necessary in order to carry and give full value to the amount of pitch which must be handled in one mopping. One of the troubles with built-up roofing as ordinarily laid is the difficulty in getting thorough moppings between the felt layers.

The felts are saturated with tar about as it comes from the gashouse, with the water and other impurities removed. Oil-tar with its liquid qualities is said to be much used for this purpose. This is more permissible than it would be if the felt were to be exposed.

After the original two layers of saturated felt are used, the additional layers are merely to give additional thickness of wearing material, and with a roof properly laid, the greater the amount of felt and pitch used the greater the life of the roof. Ten-ply roofs have been laid. If too much pitch on top is used, it will run.

The pitch, much stiffer than tar, is made by distilling off the lighter oils and part of the creosote oils from the tar. The melting point of the pitch, a very important matter, depends upon the point to which the distillation is carried and the amount of free carbon. This should be varied somewhat to suit climatic conditions. Pitch for use in the fall in Winnipeg would be very difficult to work in New Orleans in the summer. The melting point of the pitch is not definite and in defining it a special specification is necessary. The use of a pitch with a melting point too high to allow satisfactory working and requiring the addition of fluxes on the work, giving a "cutback" pitch, is very liable to give uncertain results and should not be allowed. Worse than this is the use of tar or soft pitch stiffened by the use of land plaster, Portland cement or similar materials. This not only is uncertain in its results, but it gives a product liable to have short life. The best practice allows the use of nothing but straight run pitch.

If possible, this sort of a roof should not be applied when the temperature is below freezing.

As a matter of information, the following specifications prepared for the Supervising Architect of the United States Treasury Department are presented. They should be of value where competitive bids are asked for roofing pitch when straight run pitch is desired:

UNITED STATES GOVERNMENT SPECIFICATIONS FOR STRAIGHT RUN COAL TAR PITCH FOR ROOFING.

Coal Tar Pitch for Roofing.

The pitch shall be a straight run residue obtained from the distillation of coal tar and shall meet the following requirements:

(A) Melting point, not lower than 135 deg. Fahrenheit nor higher than 155 deg. Fahrenheit.

(B) Matter insoluble in benzol, not less than 15 nor more than 35 per cent.

(C) Specific gravity at 60 deg. Fahrenheit, not less than 1.25 nor more than 1.35.

(D) Evaporation loss, 7 hrs. at 325 deg. Fahrenheit, not over 9 per cent. for pitch of 145-155 deg. m. p., and 11 per cent. for pitch 135-145 deg. m. p.

(E) Specific gravity of distillate to 670 deg. Fahrenheit, not less than 1.07, determined at 140 deg. Fahrenheit, compared with water at 140 deg. Fahrenheit.

Methods of Analysis.

(A) The melting point shall be the temperature at which the pitch formed in a ½-in. cube and suspended in a vessel of water 1 in. above the bottom shall touch the bottom of this vessel. In making this test, the cube of pitch, formed in a suitable mold, shall be suspended on a hook of No. 12 gage copper wire, bent at right angles. The pitch shall be immersed in a 600 c. c. beaker, containing 400 c. c. of freshly boiled distilled water at a temperature of 60 deg. Fahrenheit. This temperature shall be maintained until the pitch is the same temperature as the water. Heat shall then be applied in such manner that the temperature of the water is raised 9 deg. Fahrenheit per minute, until the pitch drops to the bottom of the beaker, at which point the temperature, recorded by a thermometer whose bulb shall be level with the pitch cube, indicates the melting point.

(B) Matter insoluble in benzol to be determined by any approved method of hot extraction. The preferred method is to digest ten grams of pitch in C. P. toluol on a steam bath, decant through a filter cup consisting of two No. 575 C. S.-S. hardened filter papers, transfer residue to this filter, and extract with C. P. benzol in approved form of extraction apparatus until the washings run through practically colorless.

(C and E) The specific gravity of the original material shall be determined in any approved manner at a temperature of 60 deg. Fahrenheit.

The specific gravity of the distillate shall be taken at 140 deg. Fahrenheit, compared to water at the same temperature.

(D) Evaporate loss. This shall be the loss in weight when 10 grams of pitch, placed in a nickel dish 2 in. in diameter, is subjected to a temperature of 325 deg. Fahrenheit for seven hours.

The melting point for any given piece of work should not have a variation of over 10 deg. The variation of 20 deg. given in the specifica-

tions allow for differences in latitude and season, and the thermometer for use in determining temperature should be standardized.

The coating of gravel, crushed stone or slag helps to hold the pitch in place, protects it from wear and from the action of the elements and has considerable fire retardent value. If the material be too fine, its holding power is lessened. If it be too large, the stones are more apt to roll off and to damage the roof when it is walked upon and the pitch is not properly protected. Crushed material with its rough, sharp edges has a much better holding power than rounded gravel. It can be used to help get results on a steep roof. Sand or dirt with the gravel is objectionable, as it tends to prevent the gravel from bedding in the pitch and sometimes it mixes with the pitch, the resultant being more inert and liable to crack than the clean pitch.

In the final coating of a coal tar roof the effort is to get the maximum amount of pitch coating which can be kept in place. The flatter the roof the greater the amount of pitch that can be used and the better both pitch and gravel will stay where put. The best results are obtained when the slope of the roof is only enough to allow it to thoroughly drain. When it gets above two inches to the foot many object to its use, but the above specifications are considered by others as good practice up to three inches to the foot. Above that amount a built-up coal tar roof, using these specifications, is of doubtful economy on permanent buildings, though fairly good results have been obtained from roofs steeper than this without special precautions. One method which gives good results is the addition of some asphalt to the pitch which is used for the top coating. This must be carefully done, as an intimate mixture of the asphalt and tar pitch is not easily obtained. The tar is often prepared for use on steep slopes by the addition of some finely ground inert material, which, as previously stated, is liable to give uncertain results. Actinolite is preferred for this purpose by some of the best roofers. Portland cement and land plaster are used, but do not do as well, having chemical action on the other materials. Pitches prepared in this manner are perhaps to be preferred to stiff straight run or asphalt pitches where skilled workmen are not available, as with the latter more skill is required in application. Slag is better than rounded gravel for steep roofs. A combination of the asphalt and the finely ground material is sometimes used.

Where thorough inspection is not provided during construction the roof can be inspected by cutting a strip three feet long at right angles with the way the felt is laid before the gravel is applied. This can be readily repaired so that no damage is done to the roof.

When a built-up roof is in need of repair it can frequently be kept tight for a considerable time by patching and recoating, as may be necessary, with pitch and gravel. When the original roof was well laid it can be repaired by scraping off the coating of gravel and laying a new two or three ply roof on top.

Tile or brick can be substituted for the gravel or slag where the roof is liable to have much wear and when the structure warrants the expense. The tile are sometimes grouted in Portland cement, but a bituminous cement is usually considered better. Properly built, this makes almost an ideal roof.

The built-up coal tar roofs have shown by many years' trial their value for protecting flat roofs. Instances where a life of from twenty to thirty years has been obtained are not at all rare, but poor results due to poor workmanship and poor materials are not new. The claim that at the present time the ordinary purchaser cannot be sure of getting coal tar of the quality of the best of that formerly produced would seem to have justification. At the same time, the oil tar may be no worse than the fluxes and residuals frequently used with competing materials. Pure coal tar and coal tar pitch are still made, and the dealers in roofing materials can, if they desire, furnish materials as good as any which have been sold in the past. Such materials, of course, are not the cheapest and where competition is severe the quality is liable to suffer. About all that can now be done to get the desired results is to be willing to pay the price and trust to the dealers.

The chances for poor workmanship are many and the most thorough inspection is very desirable. The moppings between the felts can be slighted, the flashing and work around gutters and openings neglected, the materials may be adulterated on the work and the quantities of pitch and gravel cut down. The cost of materials and the cost of laying for any job can be estimated within close limits and no contracts should be let which will require a slighting of the work to avoid a loss.

As an indication of what can be done in territory adjacent to Chicago and St. Louis, the following figures may be of interest. They show actual costs on a roundhouse roof of about five hundred squares laid according to the specifications given above. The work was seventy-five miles from the gravel supply and one hundred and seventy-five miles from the headquarters of the contractor, who paid all freight and fare. This work was done in 1910 close to a railroad track, so that nothing was necessary for hauling to the work. Nothing is included for overhead or fixed charges or for profit.

Cost per square:

5 lbs. sheathing paper	$ .12
155 lbs. pitch at 60c per cwt	.93
85 lbs. felt to square at $1.65 per cwt	1.40
Nails and caps	.05
Cleats for flashing	.05
Gravel (about one-seventh of a yard)	.23
Labor, including hauling, board and railroad fare	1.15
	$3.93

Costs have been revised to show 1912 prices for materials.

Where, for temporary buildings or other causes, a cheaper roof than the standard specifications call for is desired, a saving in the quan-

tities of material can be made by reducing the number of plies. From this fair results can be obtained.

Plastic Roofing.—This is a sort of built-up roof used especially on steep slopes, where in place of using ordinary roofing pitch we have a compound of some fine inert substance with tar or some other bituminous material which is plastic when warm and which can be applied with a trowel. It is not extensively used and its application is mainly confined to the eastern part of the country. Except for steep slopes it has little value, as it lacks elasticity and because it requires considerable skill to get the proper proportions.

Built-up Asphalt Roofing.—Built-up asphalt roofs have been used with considerable success. Asphalt is much less affected by temperature changes. For a roofing cement it must have considerable proportions of flux to make it easy of application. Coal tar felts are used with asphalt roofing cements. With asphalt, the dry sheet can ordinarily be avoided. Where first-class material is used it is ordinarily expensive and it is harder to handle. Except for steeper slopes than are suitable for coal tar, its use is not recommended unless unusual conditions make it more economical.

Asphalt coatings on a concrete deck are liable to lose their adhesion to the concrete. Asphalt used on a built-up roof is liable to have a short life and the builder or built-up roofs avoids it ordinarily.

General specifications for an asphalt built-up roof cannot well be prepared because of the differences in materials, and ordinarily must come from the manufacturers of the materials.

The successful laying of an asphalt built-up roof in cold weather is a difficult matter. If the asphalt is hot enough to be properly handled, there is chance of charring the felts. On steep slopes thorough mopping is difficult, and there is chance of danger to the men. One of the chief reasons for deterioration of the asphalt is supposed to be gradual absorption, due to capillary action, of the flux into the felt.

Built-up Asbestos Roofing.—There are on the market materials for a built-up asbestos and asphalt roof. The asbestos felt is not as absorbent as are rag felts and acts more as a protection to the bitumens than as a saturant.

It is claimed that asbestos felt, acting as it does more as a protection to the layers of waterproofing material and not merely as a medium for carrying them, does not have any capillary action on the oil fluxes, and that the bitumen is so protected that it retains its elasticity and waterproofing qualities much longer than with the other types of felt. If this point is sustained, asbestos felts have a superiority for asphalt roofing over the ordinary felts which may more than overbalance the increased costs. While the experience obtained from this material is not nearly as extended as that which has been had from rag felts, these roofings have been in use for about eleven years, and we have so far found nothing to disprove this claim.

The asbestos felt has advantage, due to its freedom from action of fire and decay, and it is claimed that the asbestos roofings have a considerable value in their blanketing influence on fires inside the building covered, which the ordinary felts do not have, points the value of which we consider have been overemphasized. The asbestos felt is not in any danger of being charred by hot asphalt, which sometimes happens with rag felts.

The asbestos built-up roofings usually avoid the gravel or slag necessary with the ordinary "wool" felt built-up roofing. This freedom from the use of gravel or slag with its tendency to roll or be washed off the roof into the gutters is of some advantage. This also makes it easier to locate a leak and leaves the asbestos roofings much lighter in weight than the other types, an advantage which is probably to some extent offset by the insulating power of the much greater amounts of material used with the "wool" felt. As with all built-up asphalt roofings, difficulties encountered in the mopping make a slope of not more than three inches to the foot desirable.

At the same time the wearing qualities of the asbestos sheet is questioned. A coat of an asphalt paint is applied ordinarily.

Tar has not been successfully used with asbestos felts.

As compared with a five-ply tar and gravel roof, a four-ply asbestos roof will ordinarily cost at least from one to two dollars more a square. A three-ply roof is supposed to give good results over concrete, but for wood sheathing it would seem to be approaching too closely to the conditions met with in ready roofing, for first-class work.

This roof is ordinarily applied by the manufacturer.

PREPARED OR READY COMPOSITION ROOFINGS.

To compete with it and to meet some of the conditions where a built-up roof is not satisfactory or too expensive, innumerable prepared or ready roofings have been put on the market. These ordinarily come in rolls accompanied by the nails and cement necessary to apply them. They vary from a very light felt with the cheapest possible saturant and enough sand or soapstone coating to prevent sticking in the rolls, to a sheet so heavy that it cannot be rolled, built up of heavy felts and strengthening materials and saturated and protected by carefully prepared compounds, possibly protected also by a coating of crushed stone. The durability and fire-resisting value vary to as great a degree. Ordinarily the ready roofings are cheaper than other types, but some brands sell at prices considerably above the cost of a good built-up roof. To a certain extent the weight is designated by the ply, but there is no uniformity of practice among the different manufacturers. A two-ply roofing may mean a heavier weight than a one-ply, or it may mean two separate felts stuck together.

The saturant should be liquid enough at workable temperatures to thoroughly impregnate the felt. The protective coating should be stable and not easily affected by the elements. The saturation of the felt is

a very vital feature. This must retain its life and elasticity to keep the roofing efficient. A protective coating of material similar to the saturation is often used with the idea of helping to maintain the life of the saturating material. In any event, the coating must be elastic like the saturated felt.

With a coal-tar roofing made to be rolled, it is impossible to use nearly as much material as is found necessary for a good built-up roofing, and such a roofing, even if made in the very best manner, cannot be expected to have a life comparable with that of a first-class built-up roof. Tar is not considered the best material for a high-grade ready roofing.

To successfully saturate with most asphalts, a felt much more open than that necessary for coal-tar must be used. Asphalt must be heated to a much higher degree than ordinary coal-tar to successfully saturate, and care must be taken to avoid charring the felt in the operation. Trinidad is but rarely, if at all, used for this purpose, it containing too much mineral matter and requiring too great a heat. California oil residuals are especially suitable for saturation purposes. At a temperature of 300 degrees Fahrenheit they are almost as limpid as water and at this temperature there would be no danger of charring the felt. They come between the so-called natural asphalts and coal-tar in their saturating properties and their susceptibility to changes in temperament.

The objections to asphaltic compounds for built-up roofings do not all apply for ready roofings made in the factory. Since the amount of material used is less, its cost is not of such great importance. None of the asphalts have all the desired qualities, and to produce certain results compounds of several different asphalts, residual pitches and fluxes are frequently used together. It is our understanding that Trinidad asphalt is seldom used as a protective coating, except in combination with other asphalts. Tar is sometimes used as a flux. Wax tailings, a residual obtained from petroleum in the manufacture of paraffine wax, and other similar substances are common ingredients. Resin, which gives better saturating power to many asphalts, making the solution more liquid, is also used. It must not form too large a proportion of the total, as it tends to make the final product brittle. Candle tar pitch or stearine pitch, obtained from packing-house or cottonseed oil residues by the action of sulphuric acid, is used in the coating of many ready roofings. It is stable and elastic, acting somewhat like the blown oils, and is said to be practically unaffected by the action of the sun.

The cement for use in laying, which is furnished with the roofing, ordinarily contains some naphtha or something similar which serves as a drier. To avoid becoming brittle too quickly, a material which must be heated before application is necessary.

Some ready roofings are adjusted by the manufacturer to suit the climate at the point of application. One concern selling all over the world keeps careful records of the temperature at its different markets and makes shipments accordingly.

The prepared roofings may be divided into two general classes—smooth and stone-surfaced. The stone-surfaced roofings are to a certain extent an adaptation of the built-up roofings. They frequently have at least two felts cemented together. The gravel or slag used must be uniform in size and finer than that available for a built-up roof. The steeper the roof the more chance they have to lose their stone coating. The amount of material that can be used in the heavier brands is limited to the amount that can be successfully rolled. If the stone is too large, the stone may damage the felt in rolling; if too small, the amount of pitch is limited.

The smooth-surfaced roofings are usually coated with some finely divided material to prevent sticking in the roll. Tar is not suitable for their protective coating. The protective coating must be stable and not easily affected by changes in temperature. Blown oils are frequently used for this purpose. The smooth-surfaced roofings, as a general proposition, have less insulating and fire-resisting value than the heavier stone-surfaced materials, and with them a regular recoating or painting is frequently necessary in order to get satisfactory results. This point and the chances of getting the necessary regular attention should be considered in making selections.

Tarred felts in which there are two or three plies of felts cemented together with pitch are sold all ready to be laid. They must be covered with a tar coating upon laying and at frequent intervals to show any value at all.

The asbestos roofings are made to include one or more plies of asbestos felt, sometimes with a jute center. They are cemented together by asphaltic cements. In the heavier brands they are as expensive as a five-ply built-up tar and gravel roof. The asbestos felts are poor saturants. These roofings give promise of good results and are widely used. The asbestos will not burn, but the amount used is so small that its insulating value is not great, and the value of these roofings from the standpoint of fire protection is probably frequently overestimated.

Burlap or jute canvas is used in ready roofings as a strengthening material. It is not a good saturant and must be kept thoroughly coated, as otherwise it goes to pieces readily. It is employed in conjunction with either felts or asbestos sheets. We question its value, feeling that better results can be obtained from a proper quantity of ordinary felt.

The ready roofing is weak in that with the narrow lap and a large part of the roof covered with but one layer of material a single defect can cause a leak. The fact that on a flat roof water is liable to back up under the upper layer is a chance for trouble. Care should be taken that a nail is not driven into a crack in the roof sheathing, as the nail will work out, leaving a hole in the felt for entrance of water. The exposed nailing, where it is used, may rust out and can cause a tear or leak around the nail hole. This exposed nailing is avoided in various ways. Some of the manufacturers of stone-surfaced

roofings finish the upper part of the sheet, which is to be covered by the next sheet, without any stone coating. The next layer is cemented on this strip. The only nailing necessary is thus done on the covered strip, where it is covered up by the sheet above.

The use of tin caps under the head of nails to secure prepared roofing should be avoided. When used, they must be kept constantly coated to prevent the rapid disintegration of the steel plates of which they are composed. If this occurs the nail head stands clear of the roofing, which is then an easy prey to wind storms. Care should be taken in the flashing and around the edges of the roof to have it thoroughly fastened down. Some recommend nailing every two inches, but with large-headed nails every three inches is usually considered enough.

One of the chances for trouble with many of the ready roofings is their tendency to stretch and wrinkle and the difficulty in laying them absolutely tight and flat. As the roofing grows older and brittle, the wrinkles become danger spots which are liable to crack if walked on. The roofing should be as thoroughly stretched as possible in laying. Knot holes should be covered before applying the roofing. In cold weather it is well to warm the rolls to avoid any chance of cracking.

To secure architectural effect on steep roofs a prepared roofing may be applied in various ways. For instance, by running the felt with the pitch of the roof, the joints and roofing nails can be covered with a molded batten of wood about ⅞ in. x 1½ in., the under side of which should be rabbeted out to a depth of an eighth of an inch to make room for the heads of the roofing nails. The recess or rabbet is filled with cement accompanying the roofing and then securely nailed. This not only protects the nail heads driven to secure the roofing itself, but adds stiffness and further protection against high winds getting under the seams and blowing off the entire covering. Roofs so prepared have the appearance of a standing seam tin roof and the otherwise plainness of this roofing material is relieved. This adds to the cost by increasing the amount of waste as well as requiring the battens.

In order to avoid the single thickness and narrow lap, the ready roofings can be used in various combinations. A two-ply tarred felt laid under a two-ply stone-surfaced roofing or two layers of smooth-surface roofing give what is practically a four-ply roof, not as good as a five-ply, built-up roof in all details, but sometimes cheaper. A smooth-surface roofing is sometimes used under tile or slate and sometimes a prepared roofing is laid on top of old shingles.

Some of these roofings are also cut up and used as shingles. This makes a roof without some of the disadvantages of the ready roofing at a cost less than that of shingles or slate. It cannot be used on flat slopes. It is more adaptable for use on small buildings.

The ready roofings usually commence to show deterioration after they have been kept in stock for three or four months. In purchasing care should be taken to avoid stock material.

The ready roofings are of value for small and isolated buildings where the cost of laying a built-up roof would be excessive and for temporary structures where a roof of long life is not necessary. They can be laid without the special workmen usually considered necessary for built-up roofing, but careful workmanship and skill are necessary to get good results.

Most brands can be used on any slopes, but on a flat roof extra precautions are needed to avoid leaks, and on a steep roof some kinds do not do well. On steep roofs trouble from bagging is avoided by laying the strips vertically instead of horizontally. They can be obtained at almost any desired price, but ordinarily cheaper than a good built-up, coal-tar roof.

So many inferior roofings have been sold, so many have been poorly laid or used in the wrong places, so much has had to be learned by bitter experience and there is such a chance for fraud that the ready roofings are shunned altogether by many builders who want good results. But experience is being gained gradually, and they fill many needs so well that their use is bound to increase in their proper field.

Most of the ready roofings are sold under a five or ten years' guarantee, and many contracts for built-up roofs are similarly prepared. To depend upon these guarantees alone does not give satisfactory results, even though the manufacturer be financially responsible. He can expect more immediate profit by preparing a roof which he is sure will last six or seven years and selling it under a ten years' guarantee than by preparing a roof which he is sure will last for ten years. At best the life will be uncertain and with good luck a roof built for six or seven years or even less might last twice as long. If it should need extensive repairs before the guarantee runs out, there is considerable chance that the manufacturer will not be called on to make the repairs, and if he is, the loss is not great. Guarantees are liable to be so worded as to afford various loopholes for avoiding expense and they should, if relied on, be carefully scrutinized. A good roofing should last much longer than any possible guarantee can provide for. If the guarantee is made good, there still may be nothing left at its expiration.

New and untried brands are constantly being put on the market. In some of the older ones, which have gained a reputation, inferior products are substituted. Many of the best ready roofings are made of compounds whose composition is kept secret. The only way now of being fairly sure of good results is to use a brand which has been shown by long tests to meet the desired conditions and which is made by a concern with a reputation for fair dealing. The same course would seem to be desirable in the awarding of contracts for built-up roofs, though with them track can be kept of the weight of material used and the work on the roof can be inspected.

This is not a satisfactory condition, and, as indicated in the earlier part of the report, it is hoped that before many years specifications can be devised, which, coupled with the necessary tests and with efficient fac-

tory inspection, such as that the Underwriters Laboratories is furnishing for some materials, which is explained below, will do away with the ignorance and fraud now too often met with in the bituminous roofing industry. We should then be able to buy roofing with as much certainty of quality as we can now expect in ordering steel rail. To this end our Association, working in conjunction with other organizations, should do its part.

TILE.

The term tile roofing is ordinarily considered as referring to roofing made of hard burned clay tile made with overlapping or interlocking edges.

These tiles have been used in Europe for many years. In recent years the advance here in the character and extent of the use of roofing tile has been marked and rapid. This material can now be had for prices much lower than those formerly prevailing. Tile has been placed on shops and factories which would under former conditions have been covered with slate or metal composition.

Originally the cost of tile was more than slate, but at the present time the price of ordinary patterns is about the same as for a good quality of slate.

The tile to be of value must be hard burned and have a durable glaze, well made. The ordinary unvitrified tile has a slip glaze which gives a dull red color, practically the color of the back, which is not glazed. This renders the outside of the tile practically waterproof so that it cannot absorb moisture and dirt. This sort of tile is all right in the South, where there is little chance of freezing of water absorbed through the back, but in the North its use is liable to be disastrous, and in order to get proper results a vitrified tile, which is homogeneous and does not require the slip glaze, should be used. The heavy green and brown glazes, either glossy or flat, are applied either to the soft or vitrified tile. These are applied in practically the same way as the slip glaze, by washing over the tile on the upper side before burning with a solution of the glazing material. With proper workmanship and materials, the glazes can be made so that they are durable and so that the tile will not crack or deteriorate under the influences of the atmosphere.

Besides the interlocking tile, clay shingles are made, which are laid like slate and give about the same results as slate.

With tile it is a little harder to get a tight roof than with slate. Tile should not be used on a roof having a less pitch than one-quarter, and a steeper roof is preferable. With them, as with slate, the less the chance for driving snow the flatter the allowable pitch, and for this reason in the South the use of tile can be more extensive than in the North.

Where there is a chance of driving snow, it is best to make a water-tight roof of prepared roofing, preferably a thirty-pound or heavier asphalt felt laid horizontally with well-lapped, cemented and nailed joints, as with slate. Sometimes the tile are imbedded in asphalt or coal tar pitch,

but this method does not insure the best results. The waterproofing felt is better and cheaper.

It is usual to apply the tile directly over the asphalt roofing felt with heavy nails. They are sometimes fastened with copper wires from a pierced lug toward the lower end of the tile. The wire is fastened to battens nailed horizontally on top of vertically laid battens or laths and fastened on by wire. Copper wire not less than No. 12 gage should be used for this purpose. Steel wire or bands corrode quickly.

Sometimes the tile are laid directly on steel or wooden purlins, which must be placed to suit the lengths of the tile, with the omission of roofing boards and felt. This construction is objectionable when the building is to be heated, but is suitable where escape of heat through the roof is desired or not objectionable and where an absolutely waterproof roof is not necessary. When so laid, to prevent the entrance of dust or dry snow, the joints may be pointed on the under side after laying with elastic cement.

Some manufacturers of roofing tile make glass tile of the same pattern as the clay tile, so that they may be worked in with them and used in place of skylights. These glass tiles have been used on the roofs of train sheds, shops and factories.

Hips, valleys and combs of tile roof are formed of special designs for that purpose.

Roofing tiles weigh from seven hundred and fifty to twelve hundred pounds per square.

As referred to under the discussion of built-up coal tar roofs, flat roofs on expensive buildings are sometimes covered with a rectangular tile from ¾ in. to 1¼ in. in thickness, which is used as a protection to a built-up coal tar pitch roofing, and replaces the gravel. This method is especially desirable where the roof is liable to be walked on to any extent. Vitrified brick can also be used for this purpose, but they are much heavier. The flat tile or brick should be laid with asphalt joints or with cemented joints between the tile or blocks, in which case ample provisions must be made at intervals for suitable expansion joints.

It is a little harder to get a tight roof with tile than with slate. If there is any difference, the tile roof is liable to cost a little more. Tile better withstands great heat, contains more material and is so laid as to have more insulating value than slate. Properly made, it does not deteriorate through the action of the elements. It is a poor conductor of heat and cold. It is not so brittle as ordinary slate and is less liable to be damaged by settlement of the roof.

Tile, with the possible variations in color and shades, can be better varied to meet the architectural requirements of the building.

With the improvements in the manufacture of clay roofing tile, it would seem that its importance will be gradually increased.

SLATE.

Slate comes with considerably varying qualities. It should be hard and tough and have a well-defined vein, which must not be too coarse.

If too soft it will absorb moisture; if too brittle it cannot be cut and punched without splitting, and it will easily be damaged by walking on the roof. Crystals are sometimes found which disintegrate on exposure to the weather. Acid gases in the air and freezing of absorbed water tend to cause a disintegration of the slate.

The surface when freshly split should have a bright, metallic luster, be free from all loose flakes or dull surfaces, and be straight and true.

Most slates contain ribbons or seams which traverse the slate in approximately parallel directions. Slates containing soft ribbons are inferior and should not be used in good work. Hard ribbons do not necessarily indicate inferior wearing quality.

A clear, metallic ring when struck is an indication of soundness. A cracked slate gives a different sound, easily distinguishable. A soft slate gives a dull, muffled sound.

The color varies widely, but does not necessarily indicate the quality. Good, unfading black slate can be obtained. Some of the black slates fade rapidly on exposure to the atmosphere, assuming colors considerably varied. Various shades of green, red and gray may be purchased, some of which retain their original color very well.

Some slates are marked with bands or patches of a different color, and the dark purple slates often have large spots of light green upon them. These spots do not, as a rule, affect the durability of the slate.

Black ribbon slate may be obtained at less cost than strictly all black slate, and is suitable where slight variation in color is not objectionable.

GRADING OF SLATES.

Some of the leading quarries grade slate as follows:

No. 1 Clear—A pure slate without any faults or blemishes, sold under certificate of guaranteed quality.

No. 2 Clear—A slate without "ribbons," made from rough beds.

No. 1 Ribbon—As well made as No. 1 Clear, except that it contains one or more "ribbons" (black bands or streaks across the slate), which, however, are high enough on the slate to be covered when laid, thus presenting a No. 1 roof.

No. 2 Ribbon—This contains several "ribbons," some of which cannot be covered when laid.

Hard Beds—A clear slate, not quite as smooth as No. 1 Clear, but much better than a No. 2 Clear.

Slates were formerly punched for nailholes on the job only. Now, however, slates are bored and countersunk at the quarry and should be so specified, as punching damages the slates.

Stock sizes of slate range from 7 in. x 9 in. to 14 in. x 24 in. They vary in thickness from 1/8 to 3/8 in. Three-sixteenths inch is the usual thickness for ordinary sizes. For large plain roofs the larger sizes, such as 12x16, 12x18 or 12x20, are best adapted. They break a little easier, but make fewer joints in the roof, require fewer nails and better avoid small pieces at hips and valleys. For roofs cut into small sections, the smaller sizes, 7x14 or 8x16, look better.

Slate should not be laid on a roof having less than one-quarter pitch. Where the roof is flatter than one-quarter pitch, it is liable to leak from capillary attraction. Finely powdered snow driven under the slate by a high wind, later on melting and freezing, is liable to cause damage to a roof.

The best practice is to lay slate on wooden sheathing, tongued and grooved to an even thickness, and covered with a waterproof paper or felt to act as a bed and as an insulating medium. Tarred products should not be used, but a felt saturated with asphalt and weighing thirty pounds or more is preferable.

The use of an elastic roofing cement, ordinarily made up of refuse lead paint and paint skins, for bedding the courses next to gutters, valleys and hips, is quite common on first-class work. This gives an even bed near the bottom and top of the roof.

Each course of slate should lap the slate in the second course below three inches, although this can be slightly cut down on the steeper roofs.

In laying care should be taken to avoid cracking the slate by driving nails carelessly or too tightly.

The slates are fastened with two four-penny nails, one near each upper corner. The nails should have large, flat heads, so that they may get a good hold on the surface of the slate and their length should be twice the thickness of the slate, plus the thickness of the sheathing. Three-penny nails are one and one-eighth and four-penny nails one and three-eighths inches long. Composition nails should ordinarily be used for railroad buildings.

In laying a slate roof, the roofer should not walk on the slate, but should work from a ladder reaching from the eaves to a point above where the slate is being laid, or, if this cannot be done, a one-inch board with cleats on the top of it should be used so as to distribute the roofer's weight over several slates. If walking on the roof is absolutely necessary while it is being laid, it is essential that rubbers be worn.

On account of the pitch and of the smooth surface of slate roofs, where heavy snows occur, snow guards should be provided at intervals, especially along lower edges, to prevent sliding of snow and ice.

Slate roofs rank well in regard to fire hazard, although they are not as good as tile on exposure to adjacent conflagrations.

CEMENT ROOFINGS.

Reinforced concrete tile, several square feet in area, have been used to a considerable extent on shop buildings and freight houses with steel roof trusses. They are usually formed with projections, so that they can be placed directly on the purlins and held in place by their own weight, without additional fastenings. Wire glass can be successfully inserted in these tiles, thus avoiding expensive skylight construction. Their cost compares favorably with that of slate. The reports from them are good; but, unless the roof framing is stable and even, there would seem to be danger of leaks from driving rain and snow.

Small cement tile are in use to a limited extent and the criticism given concerning the reinforced tile also applies to them. They are less expensive than clay tile, but are more absorbent and brittle. Improved methods of manufacture and further tests may later develop their merits for some purposes, but no economy has so far been shown by their use.

Asbestos sheets made of Portland cement and asbestos under pressure give promise of good results. They can be made in different colors and have some desirable features. The different manufacturers use different methods and the results obtained must be used with caution, as it is claimed that the methods of manufacture have an important bearing on the results which may be expected. Shingles of this type are said to have been successfully used abroad for many years. Recent changes are said to have much improved the quality of the material.

For small buildings, or where the design is such as to make tile undesirable, they have especial advantages. Their cost is somewhat greater than good slate, but their uniformity is such that they can more successfully be laid French or diagonal method than can slate. A considerable saving can be made by laying them French method, but we do not consider this good practice with large sheets (see diagram). The material is somewhat brittle, and with this method considerably greater amounts of breakage are to be expected, especially on the points.

When new, some water may be absorbed, but as they grow older this defect tends to disappear.

The corrugated sheets should have value as a substitute for corrugated iron sheets. They must be laid with good fastenings and sufficient lap to insure against leakage. Some of these materials are strengthened by wire mesh and some with perforated steel sheets, giving a product grading toward the metal protected by asphalt and asbestos.

SHINGLES.

A wood shingle roof, properly laid and of good material, will last many years. The old clear white pine shingles, formerly obtainable, were superior to anything now on the market, but red cedar shingles of good quality can be obtained from the Pacific Coast. In the South red cypress from the Gulf States is preferable.

Dipping in linseed oil or creosote will add considerably to the life of the shingles. Creosote stains, which may be had in various colors, also add considerably to the looks of the building. They fade, but the roof can be gone over at intervals, if desired. Stained shingles are especially adaptable to small buildings, such as suburban stations, where appearance plays an important part and where it is desired to keep down expense. To get the best results the shingles should be dipped about ten inches, one by one, and allowed to dry before being used. This requires a good deal of handling and is for that reason expensive. A good deal of the stain will come off in the handling, making its use somewhat disagreeable for the workmen. Staining after laying is cheaper and gives an appearance about as good as the dipping, but does not

materially increase the life of the roof, as the stain is not back under the joint. The application of a brush coat of stain to dipped shingles after laying makes the color more uniform and lasting. Painting after laying without dipping induces decay and should be avoided.

The main objection to a shingle roof is its fire hazard. When the roof is old, especially in a dry climate, shingles crack and get out of shape, providing a place for the lodgement of sparks and materially increasing the danger from fire hazard.

Ordinary nails usually corrode before good shingles have noticeably deteriorated and proper results can only be obtained by using good nails. The exposure of the nails is not quite so bad as with tile or slate, but considering the fact that their cost is a small matter, good composition nails are recommended for this purpose. Four-penny nails should be used where the shingles are five and one-half butts to two inches or heavier. When thinner, three-penny nails are satisfactory.

California redwood shingles come five and one-half butts to two inches. Lesser thicknesses are more liable to fray and crack and have a shorter life. Shingles eight inches or over should be split before laying. For roofs where a uniform appearance is desired, dimension shingles having a uniform width are obtainable.

In laying, to avoid the chance of one joint coming over another, they should be laid with at least three laps. In using a sixteen-inch shingle not more than four and three-fourths inches should be exposed. Four and one-half inches is considered good practice.

There should be two, and only two, nails for each shingle. If more are used the shingles will crack. They should not be laid too close together when dry, or they will tend to buckle when wet.

METALLIC ROOFINGS.

Metallic roofings may be laid in large sheets sometimes without any sheathing. These sheets are often strengthened by corrugating them. They are sometimes cut up into small sheets and laid as are shingles. Sometimes they are bent into interlocking shapes like clay tiles. The first cost of these tiles (except those of copper) is much less than that of clay tiles and they do not require as heavy roof-framing.

They are also soldered together on the roof into a single structure, of which the ordinary tin roof is typical. Copper, lead, Monel metal and tin are used this way. This type is especially valuable for flat roofs.

IRON OR STEEL.

Iron or steel are largely used as a basis for metallic roofings because of their strength and cheapness.

Their corrosion, especially for railroad buildings, is the most important factor in connection with their use as roofing materials.

This question of the corrosion of iron and steel is a live one, but the following conclusions seem to be accepted by the best authorities:

The rate of corrosion depends much less upon the amount of impurities present than upon their distribution in the metal. Segregation,

strain, or anything which causes differences in electric potential, hastens corrosion. Mill scale is a very important factor, causing pitting. The better results often obtained from wrought iron as compared with steel are due mainly to the greater homogeneity of the iron. Good wrought iron is not appreciably better than good homogeneous steel.

There are some elements like sulphur which, when present in steel, tend to hasten corrosion and some, like copper, nickel and silicon, tend to retard it.

An absolutely pure iron in use on a building would not show results appreciably different from a high-grade steel, and with mill scale or internal strain might do much worse.

Accelerated acid tests are not a fair index of the value of metals for roofing purposes.

Part of the dissatisfaction with steel in recent years is due to the thin sections used. Cast iron is protected by a silicious skin formed from contact with the mold at the time of casting and it is used in thick sections.

Where two sheets of different manufacture come together on a roof galvanic action and corrosion are liable.

Much is being written on this subject. We would refer particularly to "The Corrosion of Iron and Steel," Friend, Longmans, Green & Co., 1911, and to a paper before the International Chemical Congress by George C. Whipple and Melville C. Whipple, condensed in the Engineering News, November 17, 1912.

Iron or steel may be used unprotected except by paint. This, of course, requires regular attention and unless access can be had to all the exposed metal satisfactory results cannot be had. Galvanizing, or coating with zinc, if properly done, gives excellent results. The galvanic action between zinc and iron discourages corrosion. No advantage is gained by painting except where it is desired to avoid the glossy appearance of the galvanized steel. It should not be painted until after about a year's exposure to the weather, unless a special acid treatment is given it to thoroughly clean it and give a surface which will hold the paint. Along the Gulf and at other points where conditions are similar the galvanized iron soon assumes a dull finish, which is considered preferable to painting.

One method employed in the preparation of steel for roofing purposes is to pickle the steel in acid baths to cleanse the sheets of scale and dirt. Unless this process is most carefully followed by thorough cleansing, minute particles of acid remain to form within the plate itself an agent for its final destruction. This may occur either with tin plate or galvanized iron.

Asbestos-protected metal is sheet steel covered with a coating of bitumen and asbestos. It has not been long enough in general use to show just what place it should hold.

Commercial tin or terne plate is iron or steel coated with an alloy of lead and tin. About 75 per cent. of lead is a common percentage.

There are also on the market lead-covered steel sheets coated by special processes, some of which have shown up very well in comparative corrosion tests. Their cost is but little more than that of ordinary galvanized sheets and they seem to have considerable value. They can be painted better than galvanized iron.

TIN PLATE.

When tin is specified, the coating should consist of not less than 30 per cent. pure tin, nor more than 70 per cent. pure lead. Not less than 20 pounds of the coating should be used per box of 112 sheets 14 inches by 20 inches.

A great deal of very poor coating has been put on the market by the manufacturers of tin roofing material.

Good tin plate for roofing can still be had, and where it is desired to use this material for roof covering, one of the reliable brands of hand-dipped plate, not less than IX or No. 28 gage, should be selected. Rolled tin plate should not be used for roofing, guttering or valleys.

Tin roofing must be painted, and with a good paint, to preserve it. Tin roofings can be shown which have lasted twenty or thirty years on railroad structures, but the danger of securing poor material and the cost of maintenance have made conservative builders very cautious in its use. It has the great advantage of being available for all slopes and it is adaptable to special and difficult conditions.

Plates for tin roofing should be prepared in the shop, and one side for use next to the sheathing given a coat of good paint. In soldering these sheets, rosin and not acid should be used, as the latter may find an opening in the tin coat and attack and destroy the body.

Where tin plate is used for roofing it should be with flat seam secret nailing for flat or less than eighth pitch roofs. For those of greater pitch than this, a standing seam secret nailing may be used, care being taken that the seam is not carried into the gutter, where it would interfere with drainage and also be a possible cause of leaks through water making its way into the seams. The tin strips for this should be painted before application.

There should be paper or a saturated asphalt felt under a tin roof where there is liable to be moisture from the under side. Tar paper often contains acid which corrodes the tin.

Sheet Lead.—Sheet lead has been used abroad considerably. Its main value is due to its immunity from action by acid gases, but it is expensive. It has a tendency to cold flow from its own weight, and it expands rapidly under heat.

Copper.—Good copper is not easily corroded, but it has a high rate of expansion and is expensive. It is not always possible to secure it of good quality, and impure it corrodes rapidly. It is only desirable for railroad buildings in rare cases.

Copper and Nickel Alloy.—For expensive building a natural alloy of copper and nickel, called Monel metal, is sometimes used, which works

much like sheet copper, but is harder. It is said to corrode very slowly. Zinc-sheet zinc is used for replacing tin plate.

METHODS OF APPLICATION.

SHEATHING.—Wooden sheathing improperly laid has caused the value of many good roofings to be underestimated. Green lumber should be avoided, as it will shrink in drying, with a resultant distortion of the covering material. With a prepared roofing, the felt will be given a wavelike appearance and the seams or joints forced open. With a slate roof the slate will be liable to be broken or loosened. Tin or copper coverings may be subjected to open seams and on a tile roof the shoulders in an interlocking type will be broken off. Sheathing boards should be surfaced to a uniform thickness, and ordinarily a plain board will be satisfactory. The sheathing should be thick enough to prevent the roofing nail from going through it. On some types of buildings the building should be stiffened by running the sheathing diagonally to the rafters and purlins.

In laying ready roofing on green sheathing, trouble can often be avoided by laying the roofing parallel to the sheathing, thus avoiding the tearing out of the nails on each side of a crack by shrinking or warping of the sheathing.

NAILS.—The life of many roofs is frequently dependent upon the nails and their selection is an important matter.

In considering nails, roofs may be divided into two sets. Those where the nail is partly exposed to the action of gases, as slate roof, and those where it is protected as on a built-up pitch and gravel roof. For roofs of the first class, a nail made of an alloy and known as a "composition nail" should be used. For the second class a galvanized nail ordinarily gives efficient service and is cheaper. It should have a barbed shank. Tin caps should be avoided, and where the head is exposed, as on ready roofing, the head should be heavy. Nails should not go through the sheathing nor be big enough to split it.

GUTTERS.

Gutters for many classes of railway buildings may and should be omitted. This is more particularly true of buildings with steep roofs near tracks where cinders from passing locomotives roll down the roof into the gutters and in time, unless more care is taken to keep them clean than is usual in railway buildings, the downspouts become choked and fail to carry off the water.

Gutters may be of metal, wood, or be formed in roof of the materials used in the construction of the roof, the latter being ordinarily preferable where the design of the building permits.

Wood gutters are usually of Ogee form on the outside, and owing to the thickness of shell the capacity is small for the size of the gutters. They are made in three sizes, 3x4, 4x5 and 4x6. The capacity of these sizes is, however, scarcely more than one-fourth the same size of metal gutters of equal outside dimensions. They are the most durable kind of

gutters for buildings exposed to smoke and cinders. They are usually made of fir, white pine or cypress and should be painted inside and out every few years.

Metal gutters are made of copper, galvanized steel, iron, tin or zinc. For permanent buildings, copper is preferable. All joints should be soldered and riveted with not less than four rivets for smaller sizes and should be well braced at least every four feet and proportionately increased in number for larger sizes. Cast-iron gutters are used to a limited extent.

Gutters may be built in the roof, or hanging, as the design of the building requires. Hanging gutters, which are easier to repair, and which do not damage the building if defective, are generally preferable. They should be given as much slope as practicable to the various downspouts and the outer edge of hanging gutters should be low enough to avoid chance of damage by possible backing up of water due to stopped-up gutters and conductor pipes.

The hanging gutter on slate or tile roofs can be secured as shown on page 876 and ashed with four-pound sheet lead. The lead can be bent back and the gutter renewed without tearing up the lower course of roofing.

While gutters should be pitched to down spouts, still with moulded ones this cannot be done, except one having false bottoms, which are not recommended for railroad work.

Where gutters are required, sheet lead makes the best eave gutters on a permanent shop building, but it is expensive.

Great care must be taken to get the outlets of parapet gutters often enough and large enough where the gutter is carried down inside, which is generally preferable. An overflow pipe through the parapet wall must be made at the high point of the gutter. The bottom of the overflow should not be less than five inches above the lowest point of the gutter bed, but not high enough to cause the water to overflow any flashing that the gutter may be provided with, either on the side of the parapet wall or under the slate or tile.

Where long gutters are used expansion joints must be provided.

Copper and galvanized iron or zinc must not come in contact on a roof, as rapid corrosion due to galvanic action takes place.

FLASHING.

A large part of the trouble with roofing comes from leaks due to poor flashing around the edges, at gutters, parapet walls, and openings. Provision must be made for expansion and contraction, due to heat and cold, to loading and settlement and to shrinkage. It must be used far enough back to prevent any possible backing up of water. It is advisable to use as little metal as possible.

Special care must be used in working up against parapet walls, as with two kinds of material this is difficult. Special terra cotta block to insert in the parapet wall and give a point of application for the roofing

material is on the market. It is valuable and would be more used were it not for the trouble in getting this special material on the ground unbroken and in getting it properly set in the wall.

On a composition roofing the edges should be cut off to a straight line and project over above the gutter.

For a built-up roof a metal gravel stop is desirable. Where no other metal work is used, a wood strip is used. For concrete the edge of the roof should be provided with a wooden nailing strip fastened by a bolt inserted into the concrete.

The accompanying diagrams are presented as giving examples of good practice under different conditions.

The following definitions are presented as information concerning flashings. The numbers accompanying the different diagrams refer to the numbers of the definitions:

(1) Flashings are the mechanical unions between roof surfaces and other parts of the structure intersecting and bounding the plane of the roof, and between roofs in different planes.

(2) Vertical Flashings are flashings between roofs and other parts of the structure which intersect the plane of the roof and extend through or above the roof. (Examples: Walls, parapets, combings, soil pipes.)

(3) Lateral Flashings are flashings between roofs and other parts of the structure which bound the roof or which intersect the plane of the roof without extending above it, or flashings between roofs in different planes. (Examples: Cornices, eaves, gutters, leader heads, ridges, hips, valleys.)

(4) Head Flashings are flashings which are approximately at right angles to the general slope of the roof, at the foot of the incline.

(5) Side Flashings are flashings which are approximately parallel to the general slope of the roof.

(6) Foot Flashings are flashings which are approximately at right angles to the general slope of the roof, at the foot of the incline.

(7) Expansion Flashings are flashings built of two independent parts, each of which is respectively an integral part of the roof, and of the adjoining structure.

(8) Base Flashing is that part of an expansion flashing which is an integral part of the roof.

(9) Cap or Counter Flashing is that part of an expansion flashing which is an integral part of the adjoining structure.

(10) Continuous Flashings are flashings which are integral parts of both roof and adjoining structure, without slip or expansion joint.

(11) Protective Flashing is that part of a continuous flashing which is an integral part of the adjoining structure, but which does not form an expansion joint with a base flashing.

(12) Homogeneous Flashings are flashings built of the same materials as the roof.

(13) Mixed Flashings are flashings formed of materials other than materials of the roof. (Examples: A metal base flashing for a felt roof.)

(14) Natural or Structural Flashings are flashings which are formed structurally integral with the roof or adjoining structure. (Example: A cap flashing built into a raglet in a parapet wall.)

(15) Artificial Flashings are flashings which are not structurally integral with either the roof or the adjoining structure. (Example: A "base" or "continuous" flashing supported upon the adjoining structure by adhesion of materials, or outside cleats.)

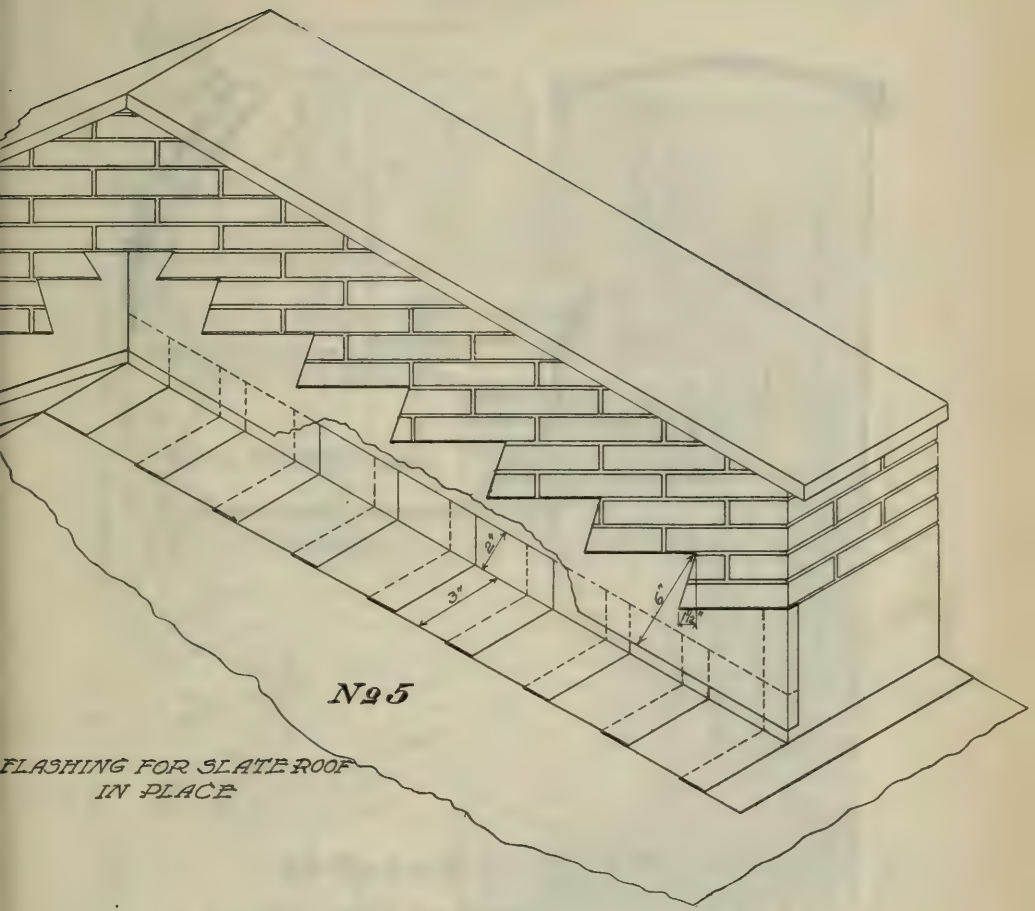
CONCLUSIONS.

The Committee recommends the substitution for the last conclusion in the Manual under roofing (reading as follows: "Steel or impure iron materials should be avoided no matter how protected") of the following:

The various metallic roofings have an important place among the roofing materials. Care must be taken to have them properly used and protected.

In using iron or steel for roofing purposes, every effort should be made to get a metal of best quality.

The roofings using Portland cement, either with reinforced concrete or with asbestos, have value under the proper conditions.



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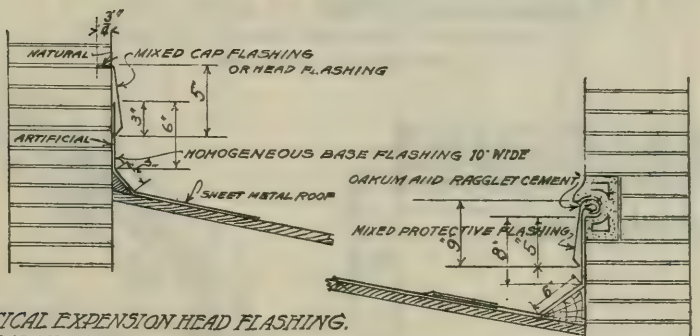
FLASHING FOR SLATE ROOF IN PLACE



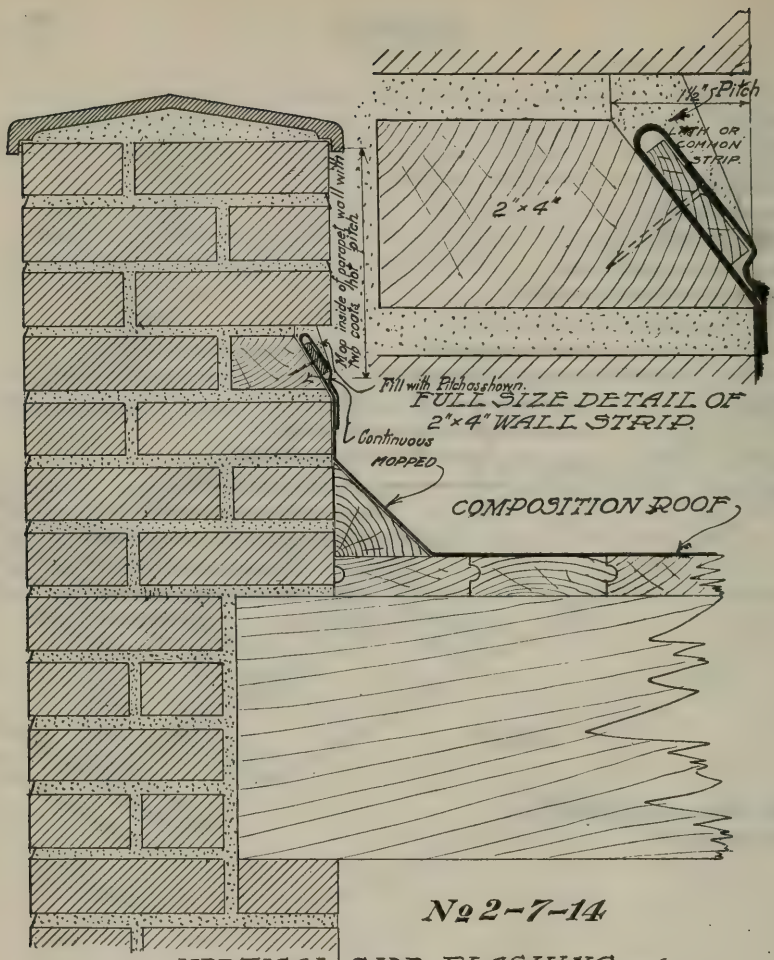
VERTICAL EXPENSION HEAD FLASHING. HEAD FLASHING AGAINST PERPENDICULAR WALLS

№ 2-4-7-9-12

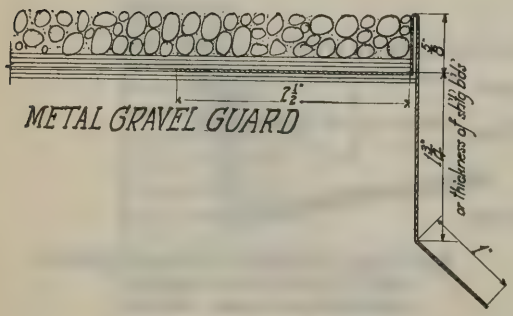
VERTICAL CONTINUOUS FOOT FLASHING FOOT FLASHING AGAINST PERPENDICULAR WALLS

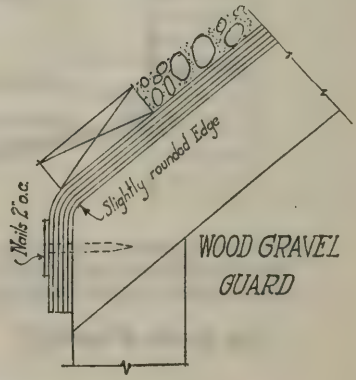
№ 2-6-8-9-11-14

DETAILS OF FLASHING AND COUNTER FLASHING FOR ROOFS AND WALLS.

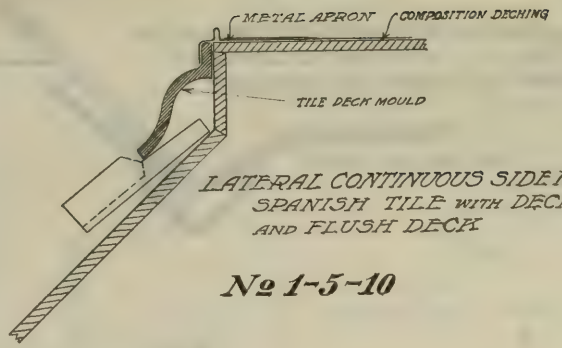


VERTICAL SIDE FLASHING.
SECTION THROUGH WALL FLASHING
ON BRICK WALLS.



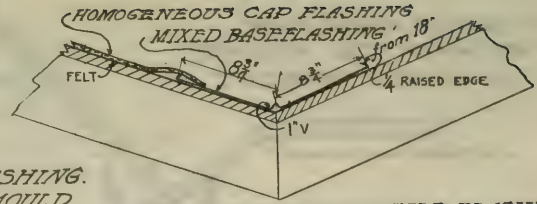


DETAILS OF FLASHING AND COUNTER FLASHING FOR ROOFS AND WALLS



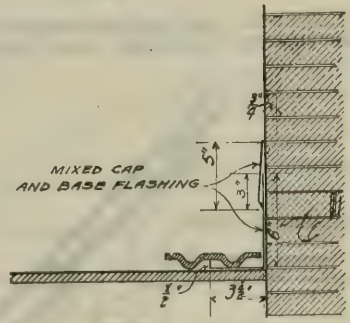
LATERAL CONTINUOUS SIDE FLASHING.
SPANISH TILE WITH DECK MOULD
AND FLUSH DECK

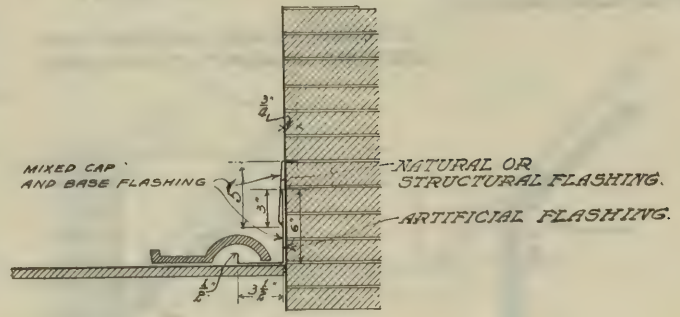
№ 1-5-10



LATERAL EXPANSION SIDE FLASHING.
SHOWING VALLEY METAL MINIMUM WIDTH.
WIDTH OF METAL VARIES WITH LENGTH OF
VALLEY AND DISCHARGE OF WATER.

№ 1-3-10





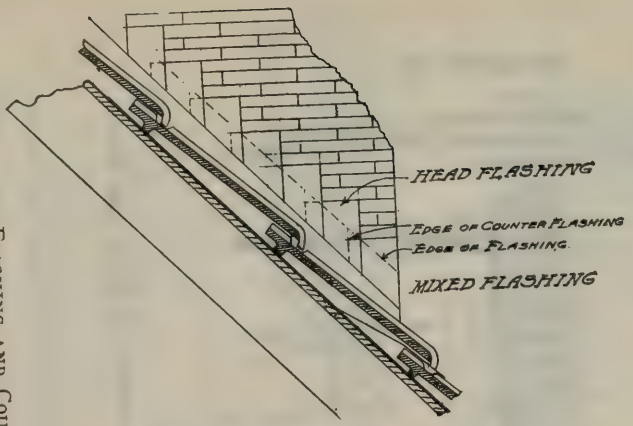
VERTICAL EXPANSION SIDE FLASHING

FLASHING AGAINST PERPENDICULAR WALLS
FOR INTERLOCKING TILES.

№ 2-7-9

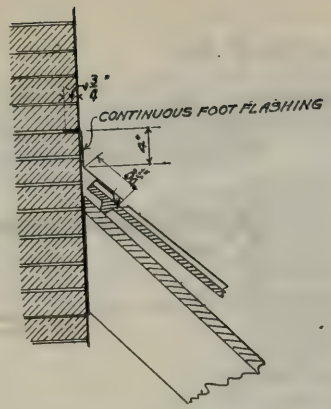
FLASHING AGAINST PERPENDICULAR WALLS
FOR SPANISH TILE

№ 2-7-9



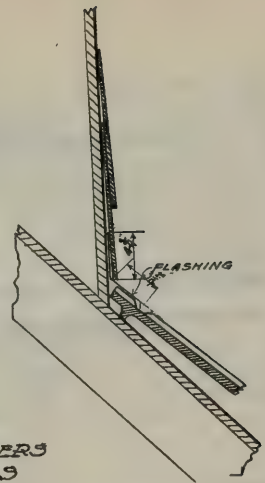
FLASHING AGAINST PERPENDICULAR WALLS
FOR INTERLOCKING AND SPANISH TILES

№ 4



FLASHING AT BASE OF DORMERS
AND AGAINST BRICK WALLS

№ 2-10

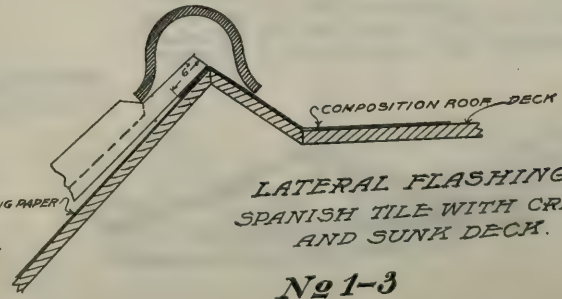


CONTINUOUS FLASHING.
FLASHING AT BASE OF DORMERS
IN CONNECTION WITH SIDING TILE

№ 2-10

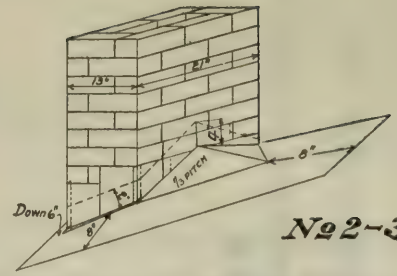
LATERAL FLASHING
INTERLOCKING TILE
WITH CRESTING AND SUNK DECK

№ 1-3



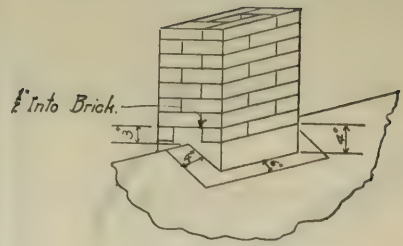
LATERAL FLASHING.
SPANISH TILE WITH CRESTING
AND SUNK DECK.

№ 1-3



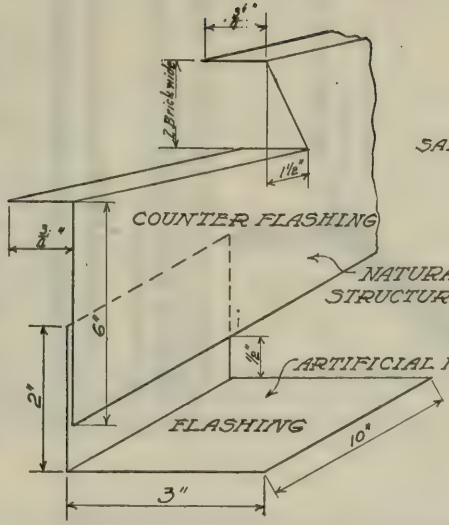
SADDLE FOR CHIMNEY THROUGH SLOPE OF ROOF

№ 2-3



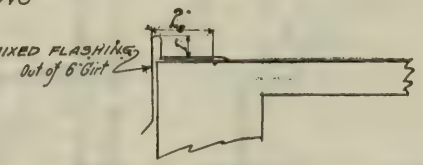
FLASHING FOR CHIMNEY THROUGH RIDGE

№ 2-3



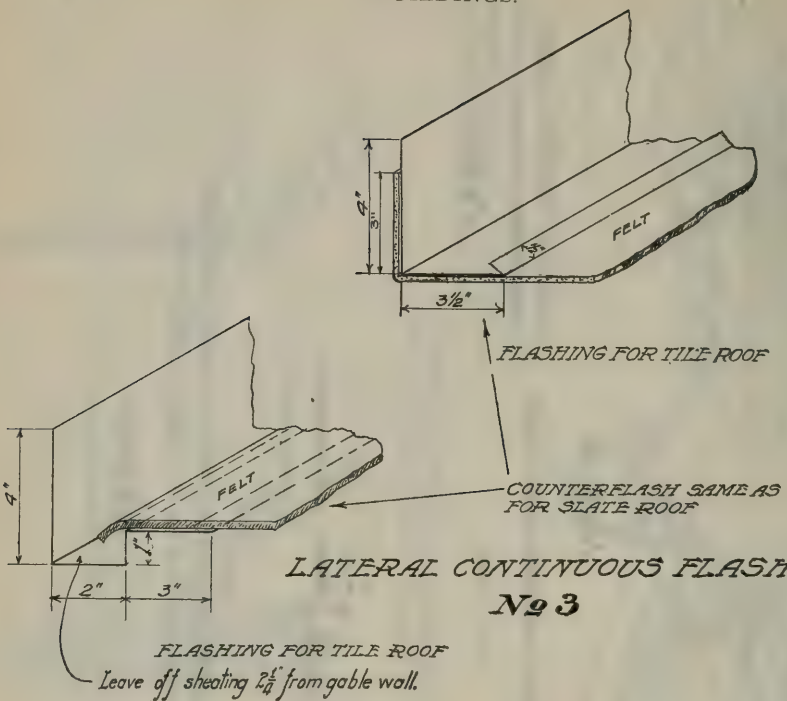
FLASHING AND COUNTER FLASHING FOR SLATE ROOF.

№ 14-15



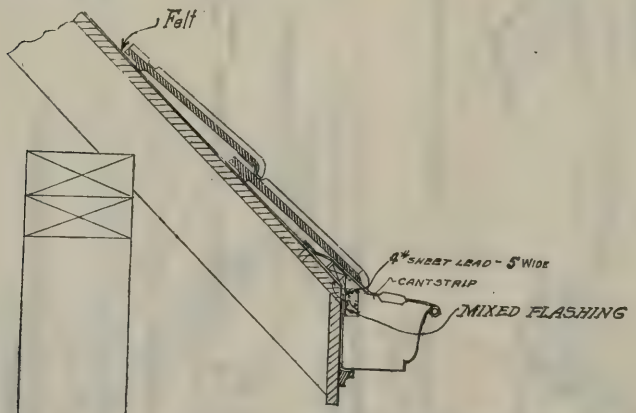
LATERAL CONTINUOUS SIDE FLASHING.
FLUSH DECK AND SIDE FLASHING.

№ 5-13



LATERAL CONTINUOUS FLASHING.

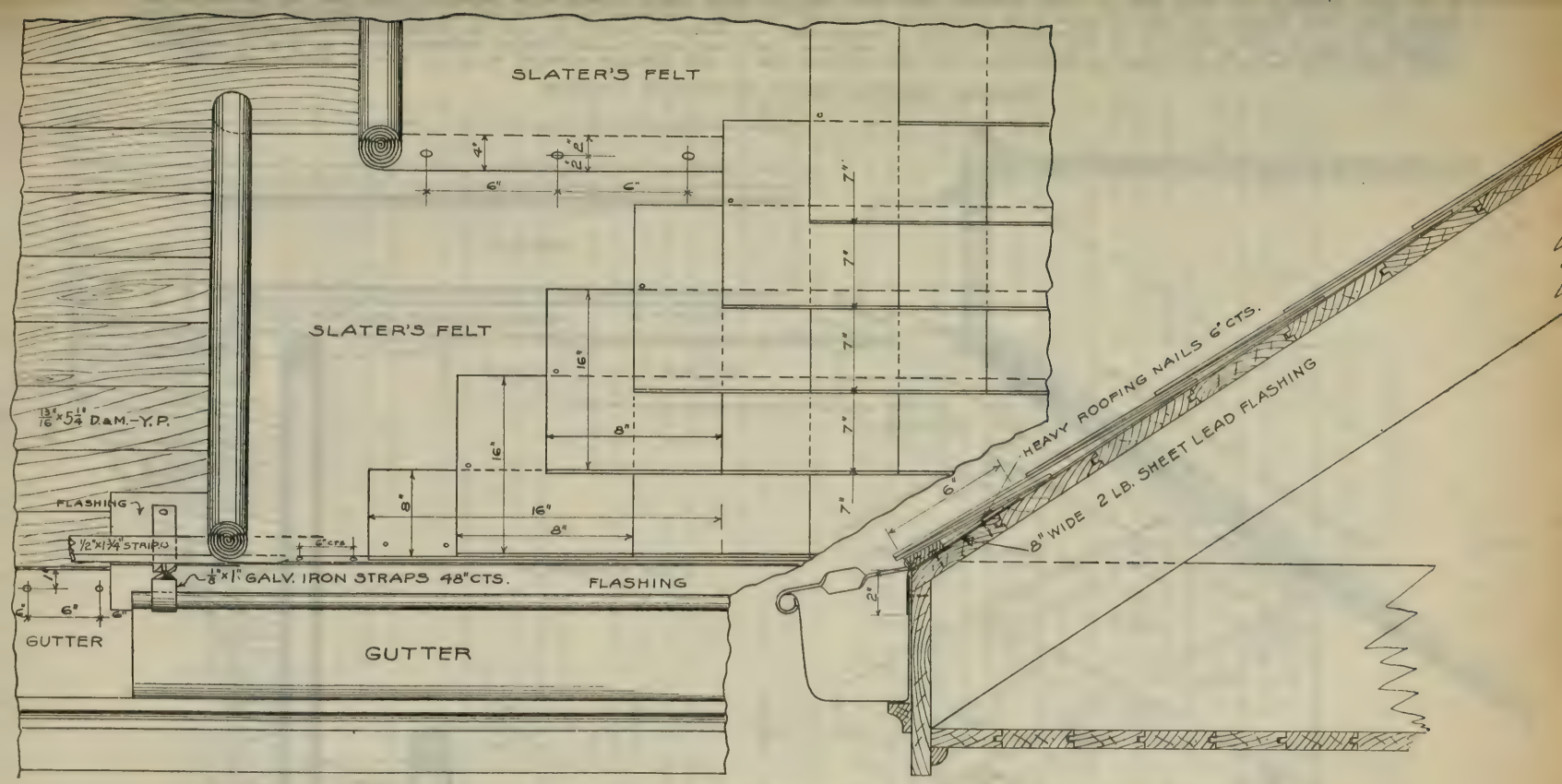
№ 3



LATERAL CONTINUOUS FOOT FLASHING
SECTION THROUGH CORNICE,
SHOWING CANT STRIP AND GUTTER METAL
UNDER TILE.

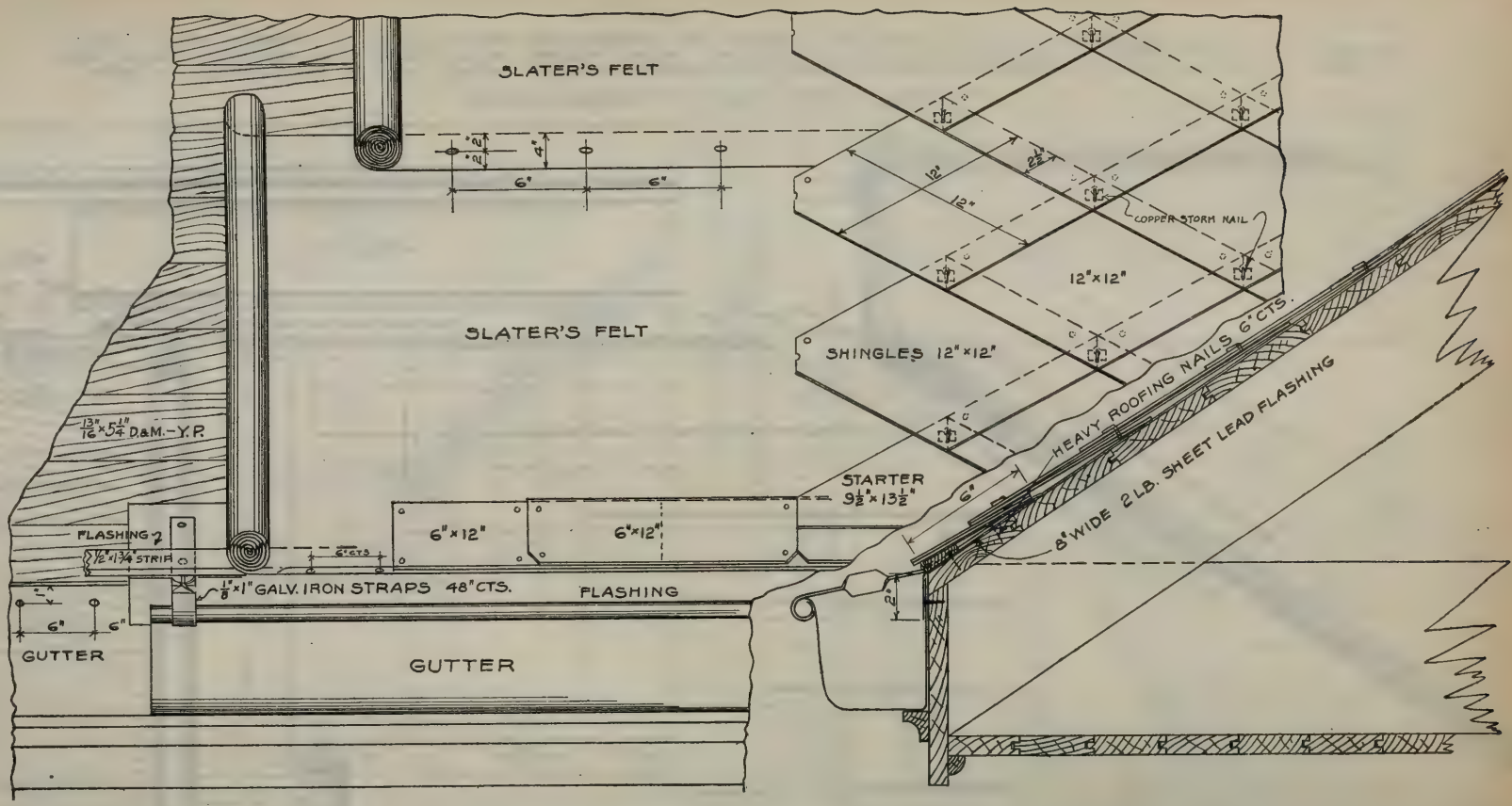
№ 3

DETAILS OF FLASHING AND COUNTER FLASHING FOR ROOFS AND WALLS.



AMERICAN METHOD OF LAYING ASBESTOS SHINGLES.

Apply one course of 8-in. by 16-in. shingles, at eaves, lengthwise and parallel to same, overhanging the eaves about ½ in. Apply the second course, using same style shingle, entirely covering course, breaking joints, after which proceed in the regular manner as with wooden shingles or slate, exposing 7 in. to the weather, and fastening each shingle in place with at least two roofing nails.



DIAGONAL METHOD OF LAYING ASBESTOS SHINGLES.

Apply one course of 6-in. by 12-in. asbestos shingles end to end, parallel with and overhanging the eaves about ½ in., over which apply one course of 6-in. by 12-in. shingles, entirely covering the first kind, breaking all joints. Starter 9½ in. by 13½ in. shall then be applied, exposing one-half lower course of the 6-in. by 12-in., as shown in detail above. Cover the balance of the roof with 12-in. by 12-in. shingles, laid as shown, exposing 9½ in. by 9½ in. to the weather. Securely fasten all shingles to place with at least two roofing nails, and fasten the points of the main-body shingles with special storm nails. All the main-body shingles shall be laid with the diagonal lines on a 45-degree angle with the eaves. Other sizes of shingles can be obtained in the same pattern.

(4) FREIGHT HOUSE FLOORS.

Freight house floors should ordinarily be built to carry a uniformly distributed load of at least two hundred and fifty pounds per square foot. They should be of materials which will not in any way damage any articles placed upon them, which will provide a surface smooth and durable, and be so constructed that they can be easily repaired.

Except for small houses, a filled-in floor, considering the cost of maintenance, is ordinarily cheaper than joist construction. It is also advantageous, because it will carry the unusually heavy loads that sometimes occur.

The usual method of construction consists of filling up to the required level with sand or gravel, thoroughly flushed and compacted. To insure a dry floor, on this filling is laid a bed of cinders about six inches thick, thoroughly compacted. In the cinders are bedded sleepers, preferably about 4 in. x 6 in., laid flat, about two feet six inches centers. These and the plank above them should be thoroughly treated with creosote or zinc chloride, where there is to be an additional wearing surface applied. With untreated timber renewal is sometimes necessary within four years, though under favorable conditions a life considerably greater is usually obtained. When no cinders are used on top of the sand the decay seems to be hastened.

In place of cinder filling and sleepers a layer of coal tar pitch spread upon a layer of sand over a course of concrete is being quite extensively used. This is durable and is said to give good results. Specifications for this method are obtainable from the coal tar producers.

Either on the sleepers, laid in cinders, or on the pitch are laid planks about two inches thick. With the pitch sub-floor the plank should be laid with broken joints toe nailed, and imbedded in the pitch by hammering until the proper stability is obtained. Care should be taken to see that they are brought to an exact grade. The plank need not necessarily be toe nailed with the wooden sleepers.

To get a smooth-wearing surface on top of the plank, hard maple is generally preferable. It does not splinter and it wears evenly. It has a short life when exposed to the weather. It is growing scarce and getting expensive. Beech is often sold for maple, they being difficult to distinguish. It is somewhat darker in color and it splinters more. Birch is softer than beech or hard maple, but does not splinter so readily as beech.

Gum, especially tupelo, is recommended as a substitute for maple and it probably will, to some extent, displace it. It is darker in color and somewhat softer, but it wears evenly and it does not splinter much more than maple. Thorough seasoning is particularly essential. There is a large supply of gum in the South and its use for floors should be extensive.

Under most conditions, the best floor can be had by laying the top floor diagonally, putting the plank lengthwise and the sleepers crosswise of the house, without any bearing on the side walls. Inequalities in

settlement of the floor are then less liable to make trouble, the plank can be laid with minimum expense, and the top floor gives the best results after considerable wear. This costs for the top slightly more for laying and more for repairs. Where there is a pronounced amount of trucking in one route, it is sometimes thought desirable to put the flooring parallel to this trucking, but where the amount of traffic warrants it would seem best to put a runway of steel plates.

Wood block pavements may be used in place of the board floor. They are best used on top of a concrete sub-floor, with a one-inch sand cushion between. With wood blocks care should be taken to obtain sufficient expansion joints, as many floors have failed from a lack of this precaution. One inch for fifty feet is about the correct amount. Care should also be taken to avoid the use of creosoted blocks where flour or similar articles which are easily damaged by odors are handled. There is also a chance of such damage from tar used in the expansion joints. Zinc chloride is for this reason recommended as a preservative for wood blocks when used for freight house floors. Zinc chloride is cheaper than creosote, and in a freight house the blocks will not suffer from the leaching which takes place when they are exposed to the weather, the main objection to the use of zinc chloride for treatment of crossties and paving blocks. It is almost impossible to get this kind of floor as smooth as a maple floor, but if properly laid it tends to wear smooth. It is adapted to points where wear is especially severe, such as are due to the handling of castings and heavy machinery. Its main advantages are in the ease with which it can be repaired. The blocks are ordinarily made of pine. It would seem that gum blocks would be better. Maple blocks are also used, but are expensive.

Concrete has been used successfully where the wear is not too severe. There is a good deal of chance of damage by falling freight, and its use must be restricted to places where there is little chance of castings and similar articles being handled, unless the top surface is carefully made of the best of hard aggregates. Under such conditions excellent results have been obtained.

A concrete sub-floor protected by a layer of asphalt mastic will give excellent results. It will cost more than the concrete floor, but it will not chip and scars made in its surface soon disappear. It is not so cold as the concrete floor and has been used for this purpose with success.

Asphalt blocks properly made would seem to have some advantage for this purpose. They should make a smoother floor than the wood blocks and be easier repaired than the mastic floor.

Respectfully submitted,

COMMITTEE ON BUILDINGS.

REPORT OF COMMITTEE XIII—ON WATER SERVICE.

ROBERT FERRIDAY, *Chairman;* J. L. CAMPBELL, *Vice-Chairman;*
H. M. CHURCH, CURTISS MILLARD,
C. C. COOK, A. MORDECAI,
G. M. DAVIDSON, W. A. PARKER,
A. F. DORLEY, CHAS. E. THOMAS,
E. G. LANE, *Committee.*

To the Members of the American Railway Engineering Association:

The Board of Direction assigned the following subjects to your Committee:

(1) Report on the design and relative economy of track pans from an operating standpoint.

(2) Report on the design of water stations using deep well pumps as source of supply.

(3) Report on recent developments in pumping machinery.

Three meetings were held, all of them in the Secretary's office, February 19, August 5, November 25, 1911.

The subjects in the hands of your Committee stand as follows:

REVISION OF THE MANUAL.

No changes to recommend.

(1) THE DESIGN AND RELATIVE ECONOMY OF TRACK PANS FROM AN OPERATING STANDPOINT.

The Committee asks for further time in which to make a final report on this subject. As a matter of information, the Committee presents herewith a valuable paper on "Track Tanks," by Mr. Geo. W. Vaughan, Engineer Maintenance of Way, New York Central & Hudson River Railroad.

(2) DESIGN OF WATER STATIONS USING DEEP WELL PUMPS AS SOURCE OF SUPPLY.

Your Committee felt that a study of deep well pumps would cover the vital subject in the design of deep well pumping stations and submits a report which outlines the various types of deep well pumps and the conditions favorable to their use. Your Committee believes that most of the members are familiar with the ordinary single-stroke steam deep well pumps, but are not acquainted with other types and with conditions essential to satisfactory operation. It was desired to submit data on efficiency, but this was found lacking. It may be possible that tests and further report can be made later. The report will serve, however, to inform the Association in a general way and probably to insure against improper installations, and it is hereinafter submitted as information.

(3) REPORT ON RECENT DEVELOPMENTS IN PUMPING MACHINERY.

Report progress. The subjects under consideration are: internal combustion engines, centrifugal pumps and turbines and the use of electric power for water stations. The latter subject is thought timely in

view of the availability of that power which is rapidly spreading through the construction of interurban roads paralleling steam roads.

(4) WATER TREATMENT.

Report progress. A study is being made of water softeners from an operating standpoint.

DEEP WELL PUMPS.

Water precipitated upon the surface of the earth as rain may be divided into three parts, basing the division upon the manner of its disposal after falling upon the soil. The first part runs from the surface in streams and rivers, into lakes and to the sea; the second by evaporation rises into the atmosphere in the form of vapor, to reappear later as rain; and the third and greater part sinks into the porous earth by percolation.

That portion of the percolating water which is not caught and utilized by growing vegetation passes downward through fissures and interstices of the earth's crust until it encounters an impervious stratum that impedes its further progress in obedience to gravitation. After filling all crevices of the earth's crust and all depressions in the impervious underlying layer to the height of unseen surrounding barriers, it escapes horizontally through the sand and porous bedded rocks, to reappear on the surface at a lower level as springs or to find its way by subterranean passages to the sea. The amount of percolating water or "ground water," is, of course, strictly dependent upon the rainfall, and the equilibrium that in the past has been reached between the water slowly escaping to lower levels through the hidden conduits and pores of the earth's crust, and the additions from intermittent rains has established an underground water surface commonly called the "water table."

When a well is sunk through the surface of the earth into a saturated or water-bearing formation, the water will rise in the well to a plane on a level with the surface of the ground water. If water is removed from the well the equilibrium between well water and ground water is disturbed and the surface of the water in the well will continue to drop until the rate of inflow from the ground to the well will equal the rate of removal from the well, at which point a new equilibrium is established. These conditions obtain strictly where a well receives its water supply from a general underground flow of ground water, but not to cases in which the draught is upon an underground pond or lake so limited in extent that its surface is appreciably affected by the pumpage. The difference in head "H" in Fig. 1 between the surface of the water in the well and the original ground water level, commonly called the "drop" or "draft," is the head that induces the flow from the surrounding porous and saturated earth into the well and which overcomes the friction between ground and ground water, the resistance offered by the

well strainer where such is used, and the friction against the sides of the well by the velocity of the water moving upward in the well.

Fig. 1 is a section through a group of deep wells operated simultaneously, and illustrates the disturbance in the ground water surface that follows the removal of water from the wells. The curved lines rising outward from the wells represent the surface assumed by the ground water level while the pumps are in operation. The distance "X," which is the radial distance from the center of the well to the point at which the drop of the ground water level is not appreciable, is known as the "radius of influence." It is apparent from this illustration that for a maximum yield of two or more wells operated simultaneously, a liberal spacing of wells is necessary in order to reduce the interference to a minimum. Theoretical formulæ have been advanced to determine the approximate radius of influence based upon an assumed porosity of the water-bearing formation and a given yield of the well, but it is here

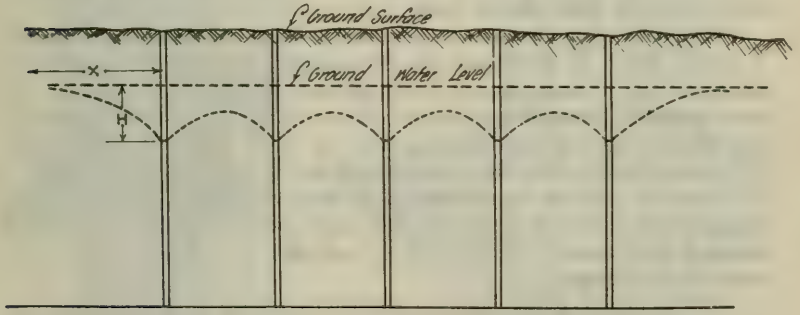


Figure 1.

recommended that for important railway work the correct spacing should be determined by an actual test wherever local conditions and the depth to the water-bearing formation will permit.

In this report a "deep well" is assumed to be a well usually of small diameter, in which the water does not stand within economical suction limits of the ordinary surface pump, or one in which the "drop" or "draft" with the desired yield brings the surface of the well water beyond an economical reach. This condition makes necessary the separation of the water end and the power end of the ordinary pump, the former being depressed into the well either to a point of submergence or within easy suction reach of the water during all its stages and the latter being placed on the surface of the ground within easy access of the boiler or other source of power. This arrangement has given rise to various devices known as "Deep Well Pumps."

Deep well pumps are of many varieties, but without attempting to include the many special devices for lifting deep ground water, those

generally used with success in railway practice can be classified under the following heads:

(1) Reciprocating, displacement or plunger pumps.
(2) Centrifugal pumps.
(3) Propeller pumps.
(4) Air lifts.
(5) Air displacement pumps.

RECIPROCATING, DISPLACEMENT OR PLUNGER PUMPS.

The old-fashioned domestic, or yard pump, is one of the first class. In this type the working barrel or cylinder is depressed in the well, either to a point of submergence, or within easy suction reach of the water, and the piston is connected with a power head located on the surface of the ground by means of a set of jointed rods of convenient length. The source of power may be either steam applied directly to the upper end of the rod as in a direct acting steam head, or a geared or belted power working head may be used.

This type of pump may have either a single-acting working barrel, in which water is discharged on the upstroke only of the piston; or double-acting, in which there are two pistons, one above the other in the same cylinder, operated by separate rods, working in opposite directions. One of the rods is a pipe and the other an inside solid rod. The inside rod is connected to the lower piston and the hollow rod to the upper.

There is also on the market a double-acting type of displacement plunger pump having a single rod and a system of valves in the barrel so designed that water is discharged on both the upstroke and the downstroke of the plunger.

Of the double-acting pumps operated by double rods there are two types. In the first, the two plungers come to rest at the same time, one at the upper and the other at the lower end of the stroke, which results in an intermittent flow. The other type, called "constant flow" or "non-pulsating" pumps, are operated on the same principle as the quick-return mechanism used on shop machinery. About 53 per cent of the revolution of each plunger is spent in the upstroke and about 47 per cent on the downstroke. The plungers therefore come up more slowly than they go down, with the result that the first plunger has completed its downstroke and has picked up the load before the other plunger has come to rest at the end of the upstroke. In other words, one plunger is always lifting, and the column of water which does not come to rest as in the ordinary type of plunger pump has a constant and practically uniform flow.

CENTRIFUGAL PUMPS.

There has recently come into use a vertical shaft, high speed, centrifugal pump of a diameter small enough to be lowered into a well of small bore to a point of submergence or within suction reach of the water in the well. The pump can be operated by a direct connected electric motor, steam turbine or with a belt drive having a quarter twist. The last

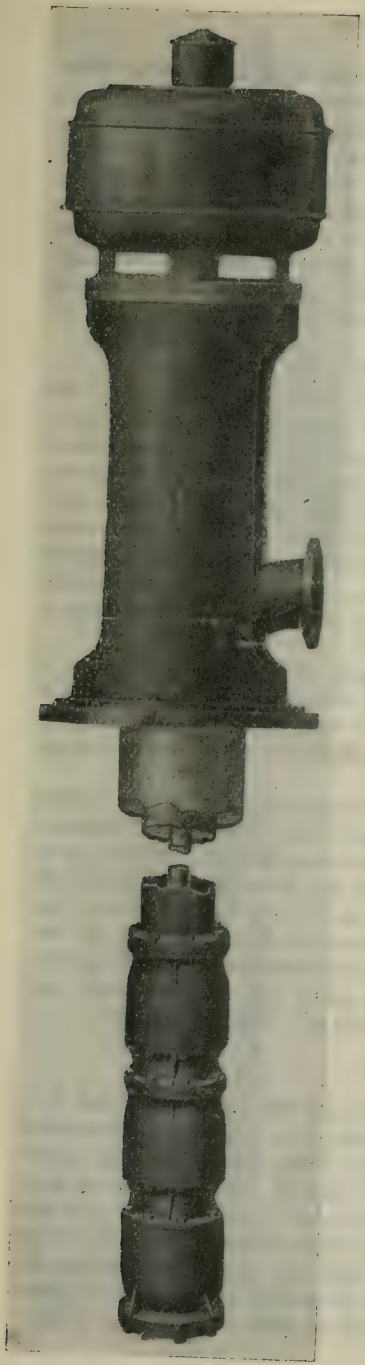


FIG. 2.

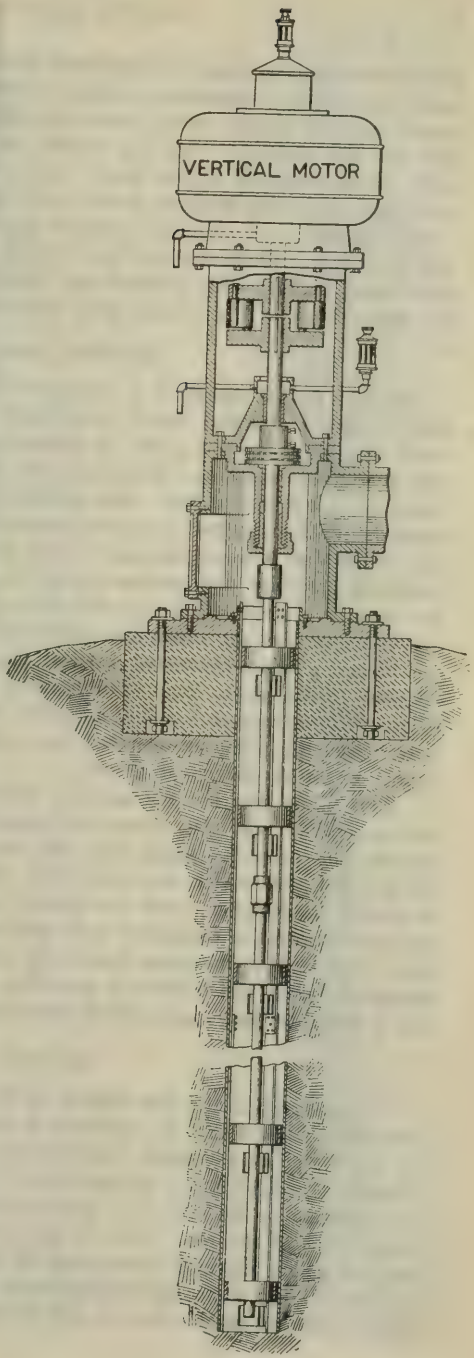


FIG. 3.

arrangement will be found less desirable than the other two, as it is rather cumbersome for a permanent railway installation. Either single stage centrifugals, or multiple stage, where the lift makes it necessary, are suitable for the purpose. They are usually made for pumping water from wells whose diameter to the water level is twelve inches or larger, and a flexible connection between motor and vertical shaft is generally used. The arrangement of a direct-connected motor driven centrifugal for deep well pumping is illustrated in Fig. 2, which shows in outline a two-stage centrifugal turbine with a balancing chamber at the bottom to receive the down thrust of the vertical shaft while in operation.

PROPELLER PUMPS.

In this device, which is a modification of the old screw-pump, the power head is attached direct to the well casing and carries a vertical shaft that extends to a point of submergence in the well, both before and during the pumping. Propellers are placed on the shaft at regular intervals of about five feet. One propeller at least must be always submerged. Each propeller is usually provided with a stationary surrounding shield that protects the well casing against injury from the rapidly revolving propeller and also serves to center the shafting. The shields are usually riveted to several flat vertical spacing bars which form a caging to enclose the shaft and propellers.

Either a direct-connected vertical motor with a flexible coupling is attached to the power head as illustrated in outline in Fig. 3, or a yoke is provided to receive a pulley attached directly to the shafting. In the latter case, the pump is operated by a quarter-twist belt from a steam engine or other source of power.

This pump was first designed to discharge the water at the surface of the ground only, but there has recently been developed a combined turbine and propeller pump that will discharge against pressure, or, in other words, lift water above the level of the power head. The turbine is placed in alignment with the power head and propeller sections and the whole forms a concentric unit that will discharge water to the desired height above the pump head. An arrangement of this kind is illustrated in Fig. 4, which shows a propeller pump with a turbine water unit and a steam turbine engine direct connected on a vertical shafting.

AIR LIFTS.

Opinions as to the true theory of the air lift differ widely, but it is generally accepted that its principle is that of a column of intermingled air and water in a vertical discharge pipe being lighter than the outside column of ground water, giving rise to a lack of equilibrium in the well, and resulting in the mixed air and water rising in the discharge pipe and overflowing at the top. The air lift consists essentially of a discharge pipe, of which the well casing may or may not form a part and an air pipe which leads the compressed air into the bottom of the discharge pipe. Many forms of nozzles for the end of the air pipe are in use, but experi-

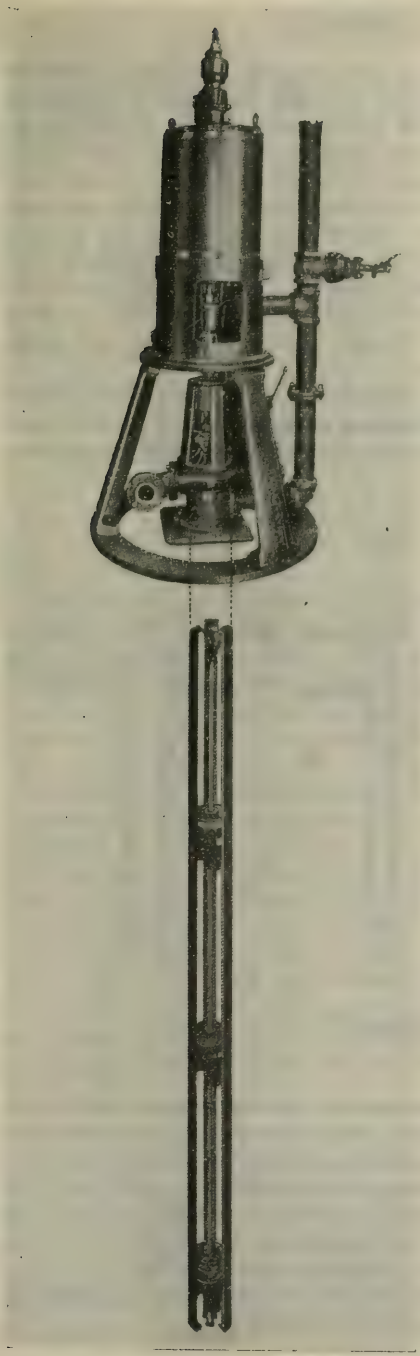


FIG. 4.

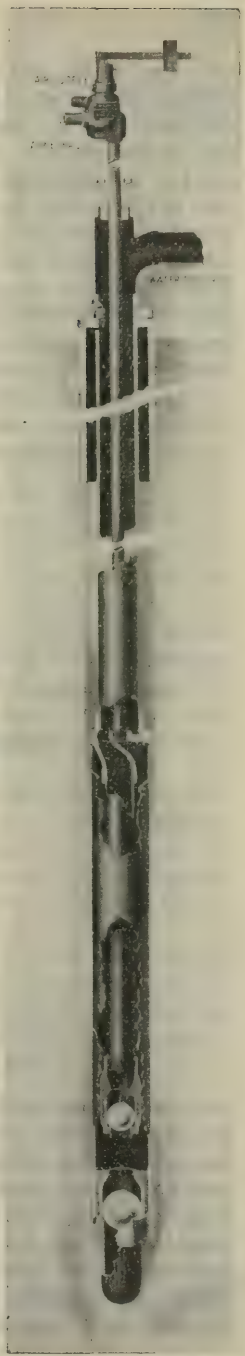


FIG. 6.

ence has shown that an open air pipe pointing downward is fully as efficient as any other form. The air pipe may be inside or outside the discharge pipe and the pressure of the air need only be slightly in excess of the pressure resulting from the static head of the water at the point of air admission. The distance "H" in Fig. 5 from the water surface in the well to the point in the discharge pipe at which the air is admitted is called the submergence. Experience has shown that for unexplained reasons best results are obtained when the submergence "H," while pumping, is about 60 per cent. of the total distance "M" between the point of air admission and the point of water discharge at the top. With greater or less submergence the efficiency of the air lift has been shown experimentally to rapidly decrease.

The diameter of the air and discharge pipes must be properly related to the quantity of water to be delivered in order to avoid undue resistance and loss of efficiency. A discharge pipe with a sectional area so large

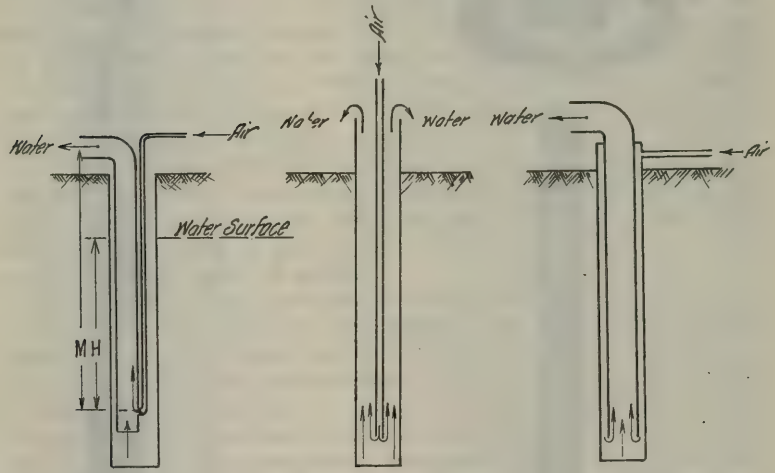


Figure 5

that the velocity of the water exclusive of the entrained air falls below four feet seems to permit the air to escape through the water with great loss of efficiency, while a discharge pipe of so limited area that velocities over six feet are attained also causes decreased efficiency, probably due, at least in part, to friction resistances. Experiments conducted in San Francisco in 1890 and mentioned in the "Engineering News" of June 8, 1893, indicate that the highest efficiency is obtained when the velocity in the discharge pipe is about four to six feet for the net volume of water discharged, not including the mass of intermingled air.

In Turneaure & Russell's "Public Water Supplies," the formula given as "commonly used for determining the relation of the various factors in an air lift problem" is—

$$q = \frac{125\,A}{h}$$

in which q = gallons of water per minute.
A = cu. feet of free air per minute.
h = height of lift in feet from water surface to point of discharge.

Fig. 5 shows three commonly used methods of arranging the discharge and air pipes in an air lift.

AIR DISPLACEMENT PUMPS.

In this device for raising ground water, the air acts as a piston upon the upper surface of the water in a discharge chamber, depressing it to a given level and discharging it through an eduction pipe to the desired point. In wells of small bore the discharge chamber consists of a vertical pipe or barrel to which is connected the air pipe at the upper end and the discharge pipe at the lower end as illustrated in outline in Fig. 6. The discharge chamber fills either by gravity or by suction. The air is admitted by a reversing valve that is actuated either by trip valves located in the discharge chamber, which in turn are operated by floats when the water has reached a predetermined level; or by the increase and decrease of pressure in the air line due to the rise and depression of the water surface in the discharge chamber.

In some types the air is exhausted into the atmosphere while in others the air is led back to the suction of the compressor under gradually diminishing pressure. The water flows into the discharge chamber by gravity as the air is displaced and if the compressor forms a partial vacuum the discharge chamber will be filled by suction to a level above that of the water in the well.

In wells of large bore, two discharge chambers are sometimes placed side by side, from which the discharge takes place alternately with a practically constant flow. The same result is accomplished by connecting two or more wells with the same delivery pipe and the same reversing valve which admits air into the several discharge chambers alternately.

CONDITIONS GOVERNING SELECTION OF TYPE AND EFFICIENCY.

It is beyond question that all the devices for raising deep ground water described have their particular field of usefulness. The intermittent flow plunger pumps undoubtedly have a low efficiency. In both the single and double-acting types, the column of water in the vertical discharge pipe comes to rest at the end of each stroke. The shock of overcoming the inertia of the column of water at the beginning of every stroke is necessarily violent and leads to great loss of power. The speed is limited to about 100 feet of piston travel per minute to prevent

undue injury to the mechanism, and this limits the yield of the well to the actual displacement capacity of the pump at this speed. In the "constant flow" or "non-pulsating" type," much higher speeds are practicable and the loss of efficiency due to the violent shock of stopping and starting the column of water is largely overcome.

Where the desired output is small and the lift is relatively low, the reciprocating pump undoubtedly has a wide field of usefulness. The first cost of installation is relatively small and the interest and depreciation charges are therefore correspondingly low. At water stations having a small output the fuel consumption, which is the factor most influenced by low efficiency, is a small part of the total cost of operation; the greater part of the operating cost usually represents the attendance and the interest and depreciation charges. However, this pump is simple and reliable and is giving good results where the yield per well or the desired quantity is small. The output can be increased approximately 100 per cent by the use of the double-acting type as compared with the single-acting, with some increase in first cost. High efficiencies are shown by the "non-pulsating" type and an increased yield is obtained on account of the higher practicable speeds. A test made by the Engineering Experiment Station at the University of Illinois with a motor-driven pump of the "non-pulsating" type showed an overall efficiency for motor and pump of 47.7 to 49.2 per cent. Subsequent experiments indicated that the efficiency of the motor was about 70 per cent. and the pump efficiency was therefore also about 70 per cent., which is unusually high.

The reciprocating plunger pump does not lend itself well for operating scattered wells unless electric power is available. The maintenance of separate steam plants is impracticable and where the character of the water-bearing formation requires a wide spacing of wells for good results, the loss in steam transmission is necessarily large; such wells, however, may be located in a straight line and be operated from a single shaft or may be located at random and operated by the device familiar in oil-producing territory, a description of such plant for a water station being given in the 1911 Proceedings.

Where the yield per well is large and large quantities are desired at a constant rate, pumps of the centrifugal and propeller types offer particular advantages. Units of this type are simple and compact, and their output is perhaps larger than that of any other device for raising deep ground water except the air lift. Relatively high efficiencies result where the type and design selected are made to fit the quantity of discharge, lift and other conditions of service. Where electricity is available scattered pumps of this type can be operated by individual motors at a minimum expense for supervision. This pump also possesses the particular advantage of successfully handling waters that contain considerable sand which in the reciprocating pump will soon destroy the wearing parts of the working barrel, but its use in wells that are not straight is not successful on ac-

count of the necessary bending and distortion of the shaft with every revolution. The maximum practical length of vertical shaft does not usually exceed 200 feet.

AIR LIFT AND AIR DISPLACEMENT PUMPS.

The air lift is not an efficient device, but it is capable of raising a larger amount of water from a small hole than any other deep well pumping method. The comparatively poor method of power application and many energy transformations can only result in limited efficiencies. However, it lends itself very well to serve scattered wells from one central power station, provided the spacing of wells is not so large as to result in excessive cost for piping the air supply. Its principal objections are the low efficiency and the disadvantage of providing the necessary submergence for best results, which under certain conditions is impracticable. The efficiency falls off so rapidly with a submergence decreasing below 60 per cent. that any wide departure from this submergence renders the loss of energy practically prohibitive. In the air displacement pump a fixed submergence for good results is not required, as it is only necessary to have the discharge chamber sufficiently submerged to insure its filling by gravity or by suction.

The air lift offers particular advantages in handling wells that contain considerable sand, as there are no valves to be affected, also in operating wells that are so crooked that the ordinary pump rod or vertical shaft cannot be used and in holes of too small bore for other methods, but unless the wells are located in the immediate vicinity of the tank, a second pump is necessary to elevate the water into the tank as the air lift will not convey water horizontally, which, however, is true only of the air lift and not the air displacement pump.

Respesctfully submitted,

COMMITTEE ON WATER SERVICE

Appendix A.

TRACK TANKS.

By George W. Vaughan, Engineer Maintenance of Way, New York Central & Hudson River Railroad.

HISTORICAL INTRODUCTION.

*Railroad construction in this country was practically in its infancy between the years of 1830 and 1840. At that time the freight schedule of a road usually included from one train a week to one a day, and the passenger schedule was not much better. The locomotives were very small and consumed little water. As might be expected, the question of water supply was about the least important one encountered.

At that time storage tanks with a capacity of 2,000 to 5,000 gallons were ample and it was many years before tanks with a capacity of 15,000 gallons became standard on the New York Central & Hudson River Railroad. The water supply, when not obtainable by gravity, was usually furnished through hand pumps, which were operated by switchmen during their spare moments. As the railroads were extended and the traffic increased the hand power for pumping was superseded by horse-power, windmills, hot-air engines, and finally by steam and electricity. The pump log gave way to the cast-iron pipe, which would stand a higher pressure and be more durable, the storage tanks were enlarged to 50,000, and even to 100,000 gallons capacity, and the old leather hose was replaced by standpipe, so that the locomotives could be watered more quickly and conveniently.

At the present time, at many of our stations, we find it necessary to provide for a consumption approaching an average of 1,000,000 gallons per twenty-four hours. The public demands an eighteen-hour schedule service between New York and Chicago, and proportionate schedules between other points. Fruit and other perishable freight must be transported at a high rate of speed. Such service does not permit frequent stops and water must be supplied to the locomotives while running at or near full speed. The cost of pumping such large quantities of water, together with fixed charges on the large investment required in equipment, reaches such a high figure that we are warranted in making expensive investigations into the methods of producing the desired results with the greatest economy.

†The railroad corporations of England felt the need of supplying water to moving trains as far back as the middle of the nineteenth century,

*See "Historical Notes on Water Supply on the New York Central & Hudson River Railroad," by C. H. Rice. Bulletin 100, June, 1908, American Railway Engineering and Maintenance of Way Association.

†See "Trautwine's Civil Engineers' Pocket Book," subject "Track Tanks," also Tratman's "Railway Track and Track Work."

and for this purpose J. Ramsbottom invented in 1861 an outfit, including a track tank between the rails and a scoop on the locomotive tender. The track tank or trough was of cast-iron, in lengths of about 6 ft., these sections being bolted together by means of flanges and the ends separated by strips of vulcanized rubber.

*It has been supposed that this was the first track tank ever put in service, but a few years ago Mr. F. W. Webb, Chief Mechanical Engineer of the London & Northwestern Railway, claimed that they were introduced on that road in 1857, and that he was engaged in preparing the first equipment.

The first track tank in the United States was built at Montrose, between New York and Albany, on the Hudson Division of the New York Central & Hudson River Railroad, and put in service in 1870. It was for the use of the fast Saratoga trains at that time and was supplied with water by a hand pump, no provision being made to prevent freezing, as its use was discontinued in the winter. Mr. Wm. Buchanan designed the first scoop, then called a "jerk water." It was attached back of the rear trucks and the conductor pipe placed back of and outside of the tender tank. The first track tank on the Mohawk Division was installed at Palatine Bridge about 1889 and the first one on the Western Division at Churchville in 1892. They were first installed on each of the four main line divisions of the Lake Shore & Michigan Southern Railway in 1893, and at Forks Creek, Tilbury and Waterford on the Michigan Central Railroad in the same year.

The use of track tanks† on the main divisions of the New York Central Lines has now become quite general. There are fourteen on the New York Central & Hudson River Railroad, between New York and Buffalo, ten on the Lake Shore & Michigan Southern Railway, between Buffalo and Chicago, and fourteen on the Michigan Central Railroad, between Buffalo and Chicago, so that trains can now run from New York to Chicago without making a single stop for water, except at the terminals, where the locomotives are regularly changed.

Many articles have been published in the Proceedings of the American Railway Engineering and Maintenance of Way Association and various periodicals on the subject of "General Water Supply," discussing the advantages of various sources of supply, the proper location of water stations, the equipment connected therewith, the relative merits of steam and gasolene, water treatment, etc., but little has been said about the details of construction of track tanks, and it is the purpose of this article to collect what data is obtainable regarding that phase† of the water question.

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*See "Modern Water Supply Stations for Locomotives" by F. M. Whyte, "American Railway Master Mechanics' Association Proceedings" of 1902.

†See "Railroad Gazette," March 13, 1908, article "Railroad Track Tanks" by H. H. Ross. Also report by Mr. S. Rockwell, Chief Engineer Lake Shore & Michigan Southern Railway, dated January 27, 1908.

LOCATION.

Track tanks are generally used on lines and divisions where traffic is dense.

From 25 to 50 per cent. of the water supplied is usually wasted by the engine scoops forcing it over the sides and ends. It is, therefore, essential that they be located where the supply of water is abundant, and on account of the large waste the ground under them will be continually soaked, so they should be placed on ground that can be thoroughly and quickly drained.

They can be operated and maintained on light curves, the Philadelphia & Reading having one, a large portion of which is on a 2-degree curve, but they give much better satisfaction and are cheaper to install and maintain on tangents. The grades approaching them must be such that all trains which are to take water can attain a speed of at least 25 miles per hour before reaching them and, for the same reason, they should be away from stations, yards, railroads crossings, drawbridges, etc.

TYPE.

Many roads followed the early practice of making the tanks of cast-iron and of bolting the sections together. The Chicago, Milwaukee & St. Paul had such a tank in use until recently between Chicago and Milwaukee. The general practice now is to make the tank of sheet steel or iron, 3/16 in. to ¼ in. in thickness, bent to the desired form.

In England many of them are supported on wooden stringers fastened to the ties, the top edge of the tank being bent over and bolted to the top of the stringers, but in this country they are usually supported directly on the ties, angle and half-round irons being riveted to the upturned sides and top edge to furnish stiffness and a means of attachment by spiking or otherwise to the ties.

A plan entitled "Plan showing sections of various track tanks now in use" accompanies this report. It exhibits the standard types in use on six representative American railroads. Especial attention is called to the new standard of the New York Central & Hudson River Railroad as here shown. It is the only one that deviates essentially from general practice.

Instead of the customary plate turned up to form the sides, it consists of two channels, with flanges turned in, which form the sides, and a flat plate which forms the bottom. It has the following advantages:

(1) It is cheaper to construct, considering the same dimensions and weight of material.

(2) The bottom of the troughs wear out much more quickly than the sides, on account of being scraped by the scoop, and this type permits the renewal of the bottom separately, thus saving considerable on repairs.

(3) Repairs are made more easily.

DEPTH.

The Midland Railway of England has on its locomotives an adjustable scoop which is lowered on approaching track tanks to a fixed point one-half inch below the top of rail. The track is depressed at the trough, six inches, the grade at the beginning and end being 1 in 360, so that the scoop dips automatically into the trough about three inches. This arrangement permits the trough to be made as deep as desired without even cutting into the ties, as illustrated in Exhibits "K" and "L."

In America the bottoms of the hopper cars, the brake rigging and other apparatus does not have as great a clearance as in England, and it is not considered good practice here to allow anything between the rails that projects above the top of them. This fixes the upper limit for the top of the track tank.

The ties under the troughs are usually eight inches thick and it is not considered safe to dap them more than 2¼ in. This fixes the lower limit for the bottom of the tank. The tanks, after a time, become somewhat uneven, often varying in height one-half inch or more. It is not practical, therefore, with a six-inch rail, to increase the depth of the tank beyond 7½ in. or 8 in. The general practice is from 6 in. to 7½ in.

Adjustable scoops are arranged so that they cannot be lowered beyond a certain point, that point being determined by the requirements of any particular railroad. The pins and bearings of the scoop, also the bearings and tires of the tender wheels wear appreciably, making a difference in adjustment sometimes as much as ¾ in. The springs under the tender become weaker with age, allowing the tender, with the scoop, to sag. Therefore, unless the adjustment is watched closely and carefully regulated it is apt to vary considerably.

The height of the tender and scoop will sometimes vary an inch or more between light and loaded conditions. Tests show that the pressure of the water against the scoop when traveling at speeds from 40 to 60 miles per hour, will pull the tender down from ½ in. to 1 in., while at speeds from 25 to 40 miles it will be affected very little. Therefore, when a scoop is lowered into a trough it is necessary to allow for a possible variation in elevation of about 2 in.

It is desirable to adjust the scoop high enough so that it will not scrape the bottom of the trough. The troughs, after a time, become uneven, making it difficult to maintain the water level less than an inch from the top. Observations indicate, and it is generally conceded that the scoop, under all conditions, must dip at least two inches below the surface of the water, in order to deliver an adequate supply into the tender tank. To meet all these conditions it is evident the track tank must be made as deep as construction considerations will permit.

Therefore a depth of 7½ in. should be used if a track tank of the usual type is adopted, or a depth of 7 in. if a type similar to the New York Central & Hudson River Railroad Standard is adopted, so as to use a standard channel.

WIDTH.

The most usual width of track tanks is 19 in. This gives about the least clearance permissible in this country, as American scoops are generally from 12 in. to 13 in. wide, and allowance must be made of about 2 in. on either side for swaying. The Midland Railway of England uses tanks 17¾ in. in width, but their scoop dippers are only 10 in. wide. Tanks with widths all the way up to 29 in. are being used in this country.

The only reason, of any consequence, for employing an inside clearance greater than 19 in., is to create sufficient storage capacity so that water may be scooped by the second engine of a double header, or by a second train following the first so closely that enough time has not elapsed for the refilling of the tanks. On the other hand, the use of the wide tank is objectionable, as experience indicates that with it considerably more water is wasted by the splashing of the scoop and this is especially true when the scoop is adjusted too low, as is often the case.

The Pennsylvania Railroad Company made some exhaustive tests in 1906 with their Standard scoop, which showed that when the locomotive was traveling at 40 miles per hour, which is considered the most economical scooping speed, they wasted 75 per cent. more water with a 29-in. trough than with one 19 in. wide. The results of their 1910 tests, as presented in Exhibit "C," indicate that, with the narrow trough, the waste is much less at all scooping speeds.

It requires more steam for preventing the wide tank from freezing, the difference being about in proportion to the surface exposed. It is stated by some authorities that the difference is even greater than the proportion of exposed surface would indicate.

The New York Central & Hudson River Railroad Company made some tests in 1910 on a 27-in. trough, which showed that the amount of water taken by the second engine of a double-header was approximately 25 per cent. of the amount taken by the first engine, in the same distance, each scooping at the same time. When double-headers are used, generally the engineers arrange that one will take water for the first half of each trough and the other for the second half, and, of course, with wide troughs the second gets some additional water, while the first is scooping, but this small extra amount can be more economically supplied by using a narrow tank and increasing its length.

This will increase the first cost and the cost of maintenance a very little, but will reduce the expense of operation quite a little, on account of the reduction in waste of water, which in turn will reduce the cost of maintaining the roadbed. It is customary to place at least three inlets in each trough, so that they may be refilled quickly. Enough additional inlet may be installed at very little expense, to accomplish the refilling in as short a time as it is practical to operate one train after another, so there is no excuse for putting in a wide tank to enable the operation of trains following each other closely. It follows, therefore, that a width should be adopted that will provide an inside clearance of 19 in.

LENGTH.

The length of various track tanks varies from 1,300 ft. to 2,500 ft. The standard lengths adopted by some railroads are as follows:

New York Central & Hudson River Railroad	1,400 ft.
Pennsylvania Railroad	1,500 ft.
Midland Railway of England	1,633 ft. 6 in.
Michigan Central Railroad	1,800 ft.
Lake Shore & Michigan Southern Railway	2,000 ft.

The last-named road has installed some 2,500 ft. long in order to furnish an adequate supply for heavy freights and double-headers, but on account of the difficulty in maintaining such a long pan level, found it advisable to cut the length down to 2,000 ft., which appears to be about the practical limit.

The most desirable length for any road must be determined by a consideration of the usual train tonnage, the grades and the distance between track tank stations, which in turn is generally governed by the available supplies and convenient locations.

Some observations were taken on the New York Central & Hudson River Railroad where the grades are moderate, in 1910, which show that heavy passenger trains of eight to twelve cars consume from eighty to one hundred gallons of water per mile, and that freight trains of about fifty loaded cars consume from one hundred and ten to one hundred and thirty gallons per mile.

Other observations taken by the same road during a test show that their Standard scoop will normally deliver into the locomotive tank about two hundred and thirty gallons per one hundred feet scooped at usual speeds.

The large locomotives have water reservoirs with capacities ranging from 7,000 to 8,000 gallons, which is sufficient to carry a heavy freight train at least fifty miles. On the New York Central & Hudson River Railroad the divisions where track tanks are used are from 140 to 150 miles long and the track tanks are from 20 to 40 miles apart, the average distance being about 30 miles. Trains will, therefore, consume in going from one track tank to the next from 2,500 to 4,000 gallons of water, on the average, for a division.

The pans being 1,400 ft. long permit scooping for a distance of 1,300 ft., and in that distance the scoops will deliver 3,000 gallons, which equals the consumption in the majority of runs. In the case of those trains consuming upwards of 4,000 gallons, it may be stated that the reserve supply in the locomotive tank at the beginning of the run will supply the deficiency. The conclusion is therefore reached that the present standard length is sufficient, except on rare occasions, under adverse conditions, and when double-headers are used. The proper length under other conditions could be determined in the same manner.

END SECTIONS.

Track tanks are generally none too long to furnish an adequate supply, and frequently enginemen, trying to get all the water possible, will leave the scoop down so long that it hits the end of the trough. Sometimes this occurs at night, when the markers have been extinguished accidentally or otherwise. Therefore, in order to avoid the cost of repairs, and more especially to prevent interruptions of service, it is desirable to construct the end sections so that the scoop will ride over them without inflicting damage.

Attached is a plan entitled "Plan showing Incline Plates at ends of various Track Tanks now in use." That of the Pennsylvania Railroad is very short and constructed on an eased curve and is backed by wood. That of the Lake Shore & Michigan Southern Railway is extremely long and solidly constructed. Those used on the Michigan Central Railroad, the Philadelphia & Reading Railway and the New York Central & Hudson River Railroad are of medium length, the first two being backed with wood and the last-named backed with plates of iron at the lower end and stiffened by angle iron throughout the remainder.

Every one of these examples is reported to be giving excellent satisfaction and there appears to be little to choose between them. It would, therefore, seem advisable to adopt a straight incline of medium length, say 10 ft., the trailing incline to be of the same length so that traffic may be reversed when desired. The plate should be ½-in. in thickness and backed with hardwood or stiff angle irons.

ROADBED AND DRAINAGE.

This topic is of considerable importance. Every railroad that operates track tanks in a cold climate realizes how difficult it is to dispose of the water spilled from scooping, quickly enough to prevent it from freezing, and heaving the roadbed and throwing the track out of alignment.

In the first place, the plant must be located where drains and ditches can be constructed that will carry away the water quickly and thoroughly. In the second place, the roadbed must be built up or constructed in such a way as to prevent, as far as possible, the water from seeping down through it, and so that the water may be carried away over a surface or paving that will not be easily washed out, to properly constructed and located surface drains, ditches, catch-basins, subsurface drains or tunnels, or some combination of these arrangements.

It is regarding these details that the practices of various railroads differ. The Lake Shore & Michigan Southern Railway has developed their drainage system further than most companies. They cover the ballast between the tracks with heavy flat stones and grade them to catch basins about 55 ft. apart. This paving prevents the ballast from being washed out and drains the water quickly into the catch-basins. Subsurface tile drains, extending longitudinally between the tracks, carry the water from

the bottom of the catch-basins into underground transverse tunnels, spaced about 333 ft. apart.

A considerable percentage of the spill always soaks through the ballast between the ties and between the paving blocks. If the subgrade is not of a character to readily dispose of this, a layer of slag 2 ft. in depth is placed below the ballast. This allows the water to find its way gradually to the catch-basins and subsurface longitudinal drains, which are laid with open joints.

The New York Central & Hudson River Railroad also lays a graded stone pavement between the tracks, but instead of removing the surface water through catch-basins and subsurface drains, they install transverse surface box drains every 50 ft., which are very effective for this purpose, and have the advantage of being easily kept open in winter. They install graded trenches filled with cobbles under the pavement longitudinally between the tracks and place transverse subsurface tile drains every 100 ft. This arrangement very readily removes the water which finds its way through the pavement and ballast.

The Lake Shore & Michigan Southern Railway layout is illustrated on the attached plan, entitled "Standard Track Tank; Circulatory Heating System," and the New York Central & Hudson River Railroad layout on plan entitled "Standard Track Tank; Drainage for Direct Heating System."

N figures were available to show the comparative cost of the two schemes; however, the cost of the former should certainly exceed that of the latter considerably, the amount depending somewhat on local conditions. It is pointed out that the tunnels serve the double purpose of providing an outlet to the drainage system and an accessible conduit for the water pipes, but the water pipes can be installed and maintained easily without the tunnels, so that most of this cost should be charged up to the drainage.

It would seem that this layout should be provided with the means to more readily dispose of the surface water in winter, when the catch-basins become frozen over, by the addition of transverse box drains on the surface at each catch-basin, as shown on the attached plan, entitled "Standard Track Tank; Drainage for Circulatory Heating System."

The New York Central & Hudson River Railroad layout disposes of the surface water quickly and is easily kept open in winter, and it will dispose of the subsurface water more quickly than the other scheme and is preferable, as it will cost less to install and maintain.

STEAM AND WATER PIPING.

The water in all track tanks on the New York Central Lines must be heated in winter to prevent it from freezing, the amount of heat required depending upon the temperature of the supply and the atmosphere, the amount of water surface exposed, the frequency of scooping and the method of applying the steam to the water. The character of the heating system determines to a large extent the arrangement of water

supply piping, necessitating a consideration of both piping systems at the same time.

Modern installations comprise in general one or more water pipes, extending nearly the full length of the troughs, with several branches connected to trough inlets. The supply is controlled by automatic valves actuated by a change in level of the water in the trough. If water is supplied through an inlet faster than it can flow along the trough by gravity, it will overflow at that point, causing considerable loss without increasing at all the rate of filling. This restriction is modified somewhat by the use of baffle plates in the inlet boxes or by dividing the inlet, discharging the water from the two sides of the pan instead of from the bottom; but, at best, the rate of flow is limited, and it is necessary to provide three or more inlets to each trough, the number depending upon the desired rate of filling.

At Herkimer, on the New York Central & Hudson River Railroad, where the troughs are 1,400 ft. long and 27 in. wide, and supplied by three inlets each, tests showed that after an engine had scooped full length, the pan would refill in from four to six minutes, the time depending upon the adjustment of the valves and somewhat upon the wind. After one engine had scooped full length, a second engine following in one and one-half minutes took one-half of a normal supply and in three minutes a full normal supply. The reason a full supply could be obtained before the trough was entirely refilled was due to the fact that the scoop was given a deeper immersion than necessary, taking in more water when the trough was full than it could deliver into the tender.

There does not appear to be much data available regarding the rate of refilling troughs, but our observations indicate that with the inlet valves adjusted to give the maximum permissible rate of discharge and with the inlets spaced about 450 ft. apart, the trough will refill quickly enough to enable trains to get a full supply when operated on a three-minute headway, which meets all practical requirements.

There are in general use two methods of applying steam to the water to prevent it from freezing, known as the "Direct" and "Circulatory" Systems, respectively. The former requires one or more pipe lines extending the full length of the troughs, with branches at frequent intervals, discharging steam through small nozzles direct into the bottom or sides of the trough. There is always more or less surging of the water in the trough, due to scooping and refilling and to the action of the wind, so that, with the nozzles spaced at intervals of 33 ft. (as per New York Central & Hudson River Railroad Standard), the heat is very evenly distributed. It is, therefore, unnecessary to maintain the temperature of the water at any point much above the freezing point, which insures a minimum loss of heat, due to exposure to the atmosphere. The steam pipes, whether laid below or above ground, are thoroughly covered to prevent loss of heat from that source as much as possible.

The Circulatory System, as used at various places, differs somewhat in the details, but its application on the Lake Shore & Michigan South-

ern Railway, in accordance with their latest standard, is typical, and is probably more perfectly developed there than anywhere. Their standard, which applies to troughs 2,000 ft. in length, shows a 4-in. water main for each trough extending nearly the full length. These are called circulatory pipes, and each has seven connections with its trough, three connections being inlets and four outlets, the inlets and outlets alternating. Steam is discharged into each inlet connection by means of ejectors, so that the water is forced to circulate while being heated.

This scheme is illustrated on the attached plan, entitled "Standard Track Tank; Circulatory Heating System, Piping Plan." The distance between inlets and outlets is about 333 ft., and when the trough is full it is not permissible to maintain a much greater depth at the inlet than at the outlet; the rate of circulation is therefore limited, and it is found necessary in severe weather to maintain a temperature at the inlet of about 60 degrees Fahrenheit in order to prevent the water from freezing at the outlet. Accordingly, the loss of heat due to exposure to the atmosphere is much greater than when the direct heating system is used.

The troughs must be watched closely, when scooping is not frequent, in order that any ice which may happen to form can be promptly removed, otherwise the ice will impede circulation, allowing a considerable section of the trough to freeze up quickly, with no means of thawing it out. After scooping the trough is refilled by means of automatic valves at each inlet connection, the water being supplied through a separate water main, which extends to each inlet pit.

The plants, at various places, of the different types differ so much as to size, capacity, temperature of water supply and in respect to other important local conditions, that it has been impossible to arrange available data so as to show definitely the comparative cost of installation, maintenance and operation of the different schemes. The direct heating system with the simple water piping layout that may be used with it is illustrated on the attached plan, entitled "Standard Track Tank; Direct Heating System."

It would appear from a study of the plans that, under similar local conditions and requirements, the Circulatory System would necessitate more piping, and, as the loss in heat must be greater, a larger boiler plant would be required, each condition operating to increase the cost of installation and maintenance. The fact that more heat is required would also cause the cost of operation to be greater. If it was desired to multiply the number of inlets, the difference in cost of installation would be increased, while the difference in cost of operation would probably be decreased, as it would not be necessary to heat the water to as high a temperature.

SCOOP PERFORMANCES.

The design and operation of track tanks and scoops are so closely related that available data on scoop performances is included in this

report. Tests have been made from time to time of the standard scoops of the Lake Shore & Michigan Southern, the Michigan Central and the New York Central & Hudson River Railroad, from which valuable conclusions may be drawn. Probably the most extensive, complete and thorough investigation of this character that has ever been made was conducted by the Pennsylvania Railroad Company at Atglen, Pa., in 1910. A detailed description of the method of conducting the experiments and the results deserves a place in this report.

*Atglen water station is located about half-way between Philadelphia and Harrisburg, and was selected for the tests because of its convenient layout and on account of troughs of two widths having been installed there. There are four main tracks north of the power house, numbered one to four, and two freight tracks south of the house, known as east and westbound low-grade tracks, all having troughs on them, so that there is an unusual opportunity to observe trains in regular service scooping water.

The tests were conducted on tracks Nos. 1 and 2, both being on a two-degree curve and having 4-in. and 3-in. elevation, respectively. Both troughs are of the Pennsylvania Railroad Standard Type, 6 in. deep, 19 in. wide on track No. 1, and 29 in. wide on track No. 2, and about 1,500 ft. long. Water is supplied by gravity, through automatic valves located in the power house, there being one valve to each pan. In winter the water is heated by a circulating system, somewhat similar to that in use on the Lake Shore & Michigan Southern, there being four inlets and three outlets in each trough.

So far as could be observed, the curve on which the track tanks are located introduces no important conditions not found where troughs are straight. Owing to the elevation in the track, the water is deeper in the trough toward the inner rail. An examination was made to see if there were signs of the dipper scraping the bottom more on that side than the other. However, slight irregularities in setting the trough made any such deduction impossible.

The pans were very generally scraped for about 15 in. in width and in places 16 in. in width, indicating a side play of about 1½ in. each way. This confirms the statement under the head of "Width," that an allowance of 2 in. on each side of the scoop must be made for swaying.

Exhibit "A" includes a sketch of the layout and also sections of the two widths of the troughs.

Exhibit "E" shows a general view of the station and a detail view of the wide trough, having walls to narrow the scooping channel and to prevent splashing.

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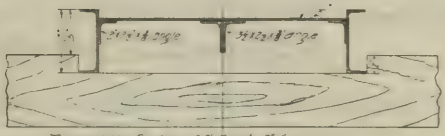
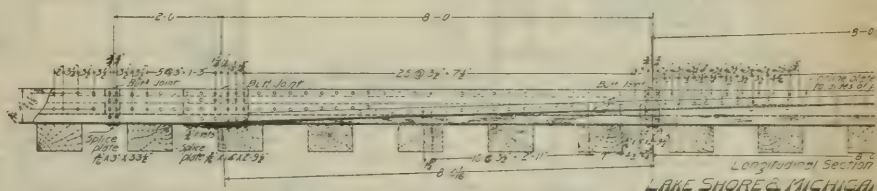
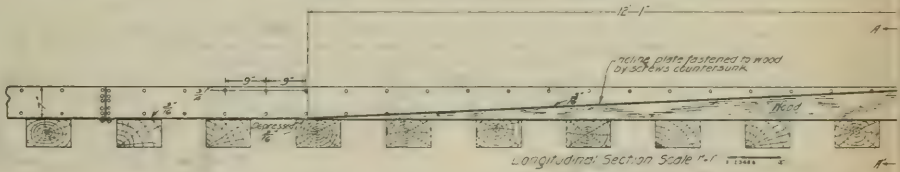
*See report made by Assistant Engineer E. L. Hurley to Mr. George W. Kittredge. The curves and other data were made available through the courtesy of Mr. E. D. Nelson, Engineer of Tests, under whose direction the experiments were conducted, and should not be published for the benefit of the public, until it is made available by the Pennsylvania Railroad Company.

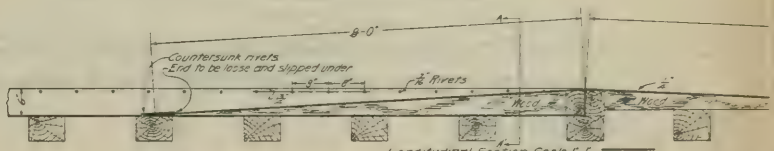
NEW YORK CENTRAL & HU

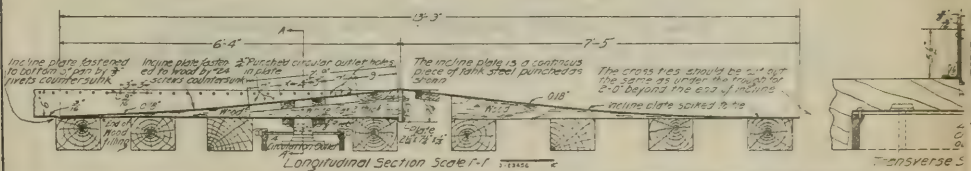




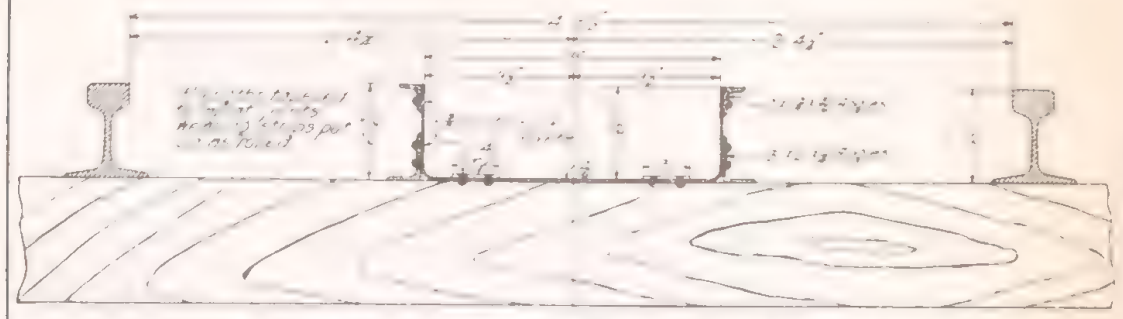
LAKE SHORE & MICHIGA





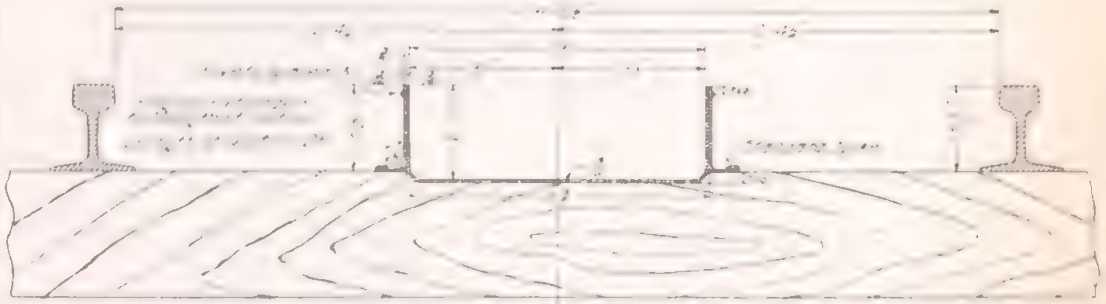

13-3"
6-4"
7-5"
Incline plate fastened to bottom of joint by ⅞" rivets countersunk
Incline plate fastened to head by ⅞" screws countersunk
2" Punched circular outlet holes in plate
The incline plate is a continuous piece of tank steel punched as shown
The cross ties should be cut out the same as under the rail for 2'-0" beyond the end of incline
Wood
Incline plate screwed to the
Longitudinal Section Scale 1"-1'

PENNSYLVANIA RAILROAD.

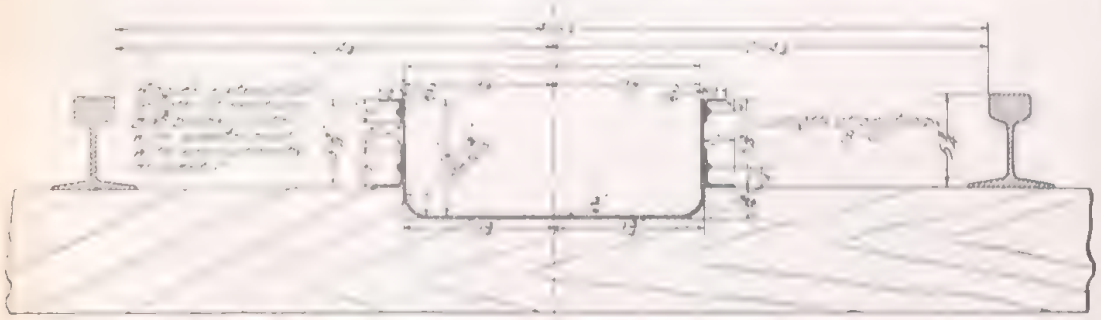


NEW YORK NEW HAVEN & HARTFORD RAILROAD.

MICHIGAN CENTRAL RAILROAD.

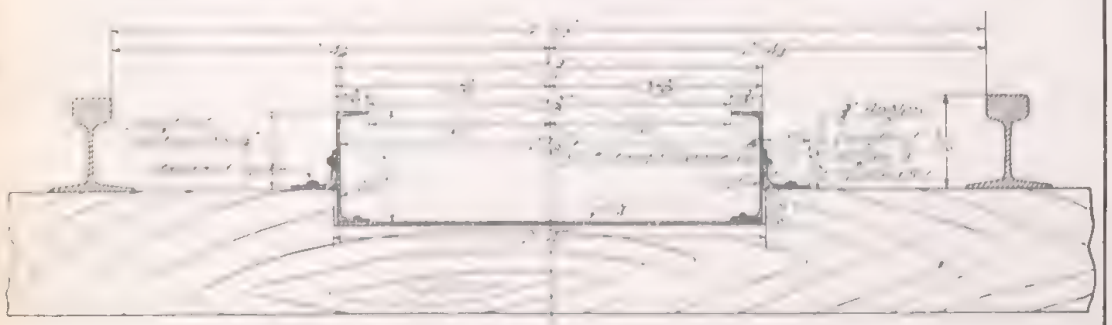


PENNSYLVANIA RAILROAD.



LAKE SHORE & MICHIGAN SOUTHERN RAILWAY.

PHILADELPHIA & READING RAILWAY.



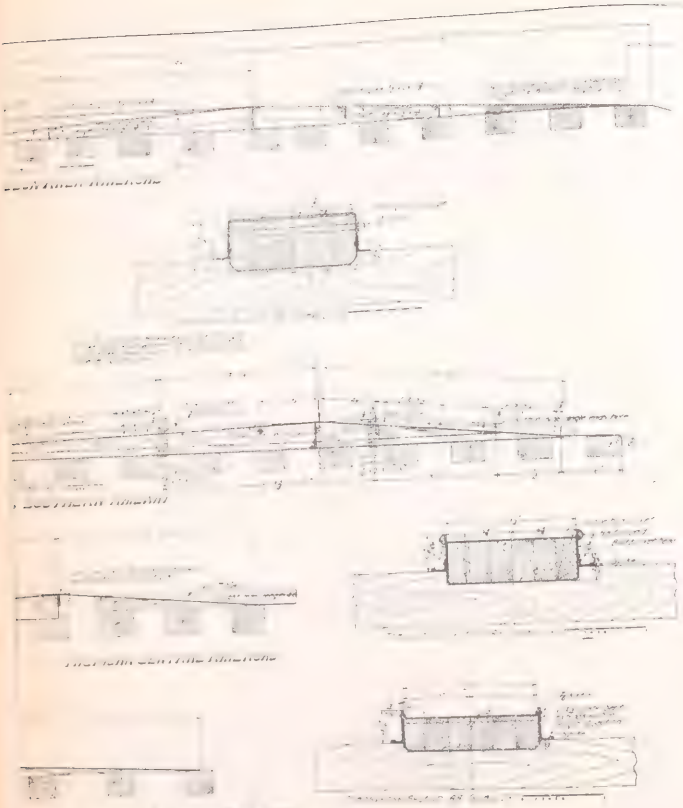
NEW YORK CENTRAL & HUDSON RIVER RAILROAD.

NEW YORK CENTRAL LINES.

Plan showing sections of various track tanks now in use

Scale 2" = 1'

New York Dec 1909

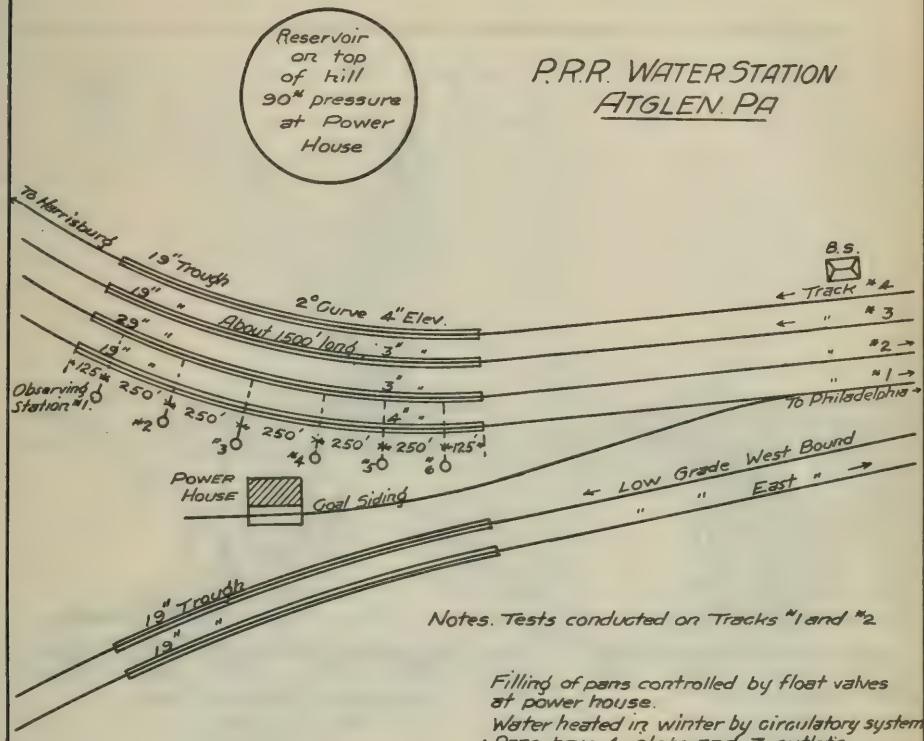


NEW YORK CENTRAL LINES.

...n showing rail tie plates at ends of switch track tanks now in use

New York Dec 1919

P.R.R. WATER STATION
ATGLEN. PA

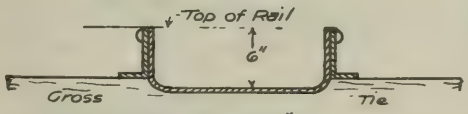


Notes. Tests conducted on Tracks #1 and #2

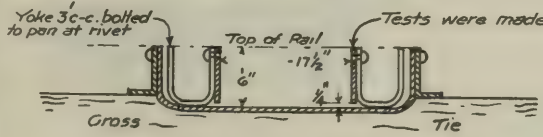
Filling of pans controlled by float valves at power house.

Water heated in winter by circulatory system

Pans have 4 inlets and 3 outlets

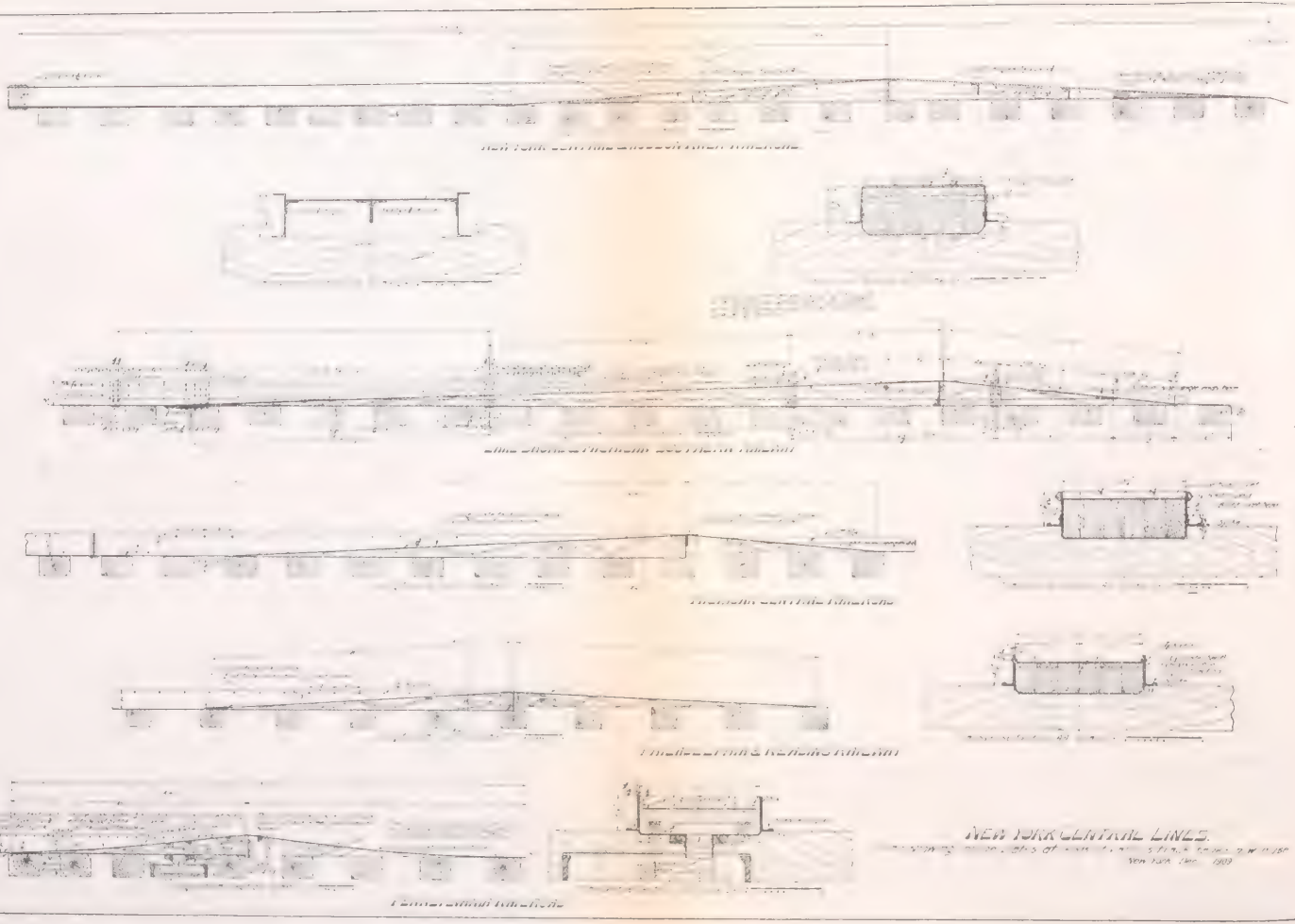


SECTION OF 19" TROUGH

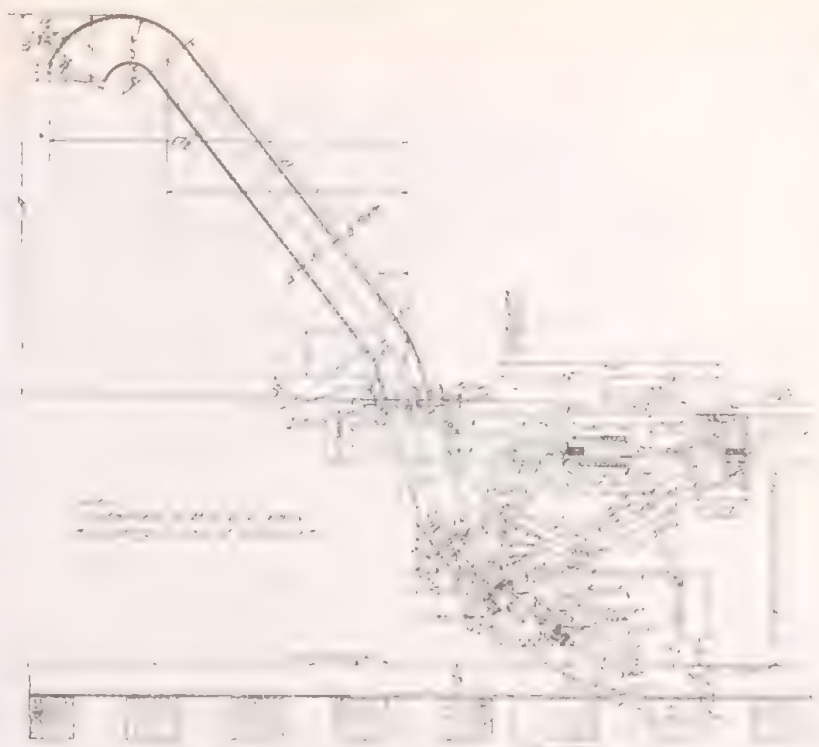


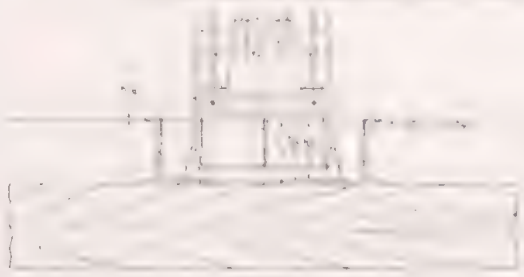
SECTION OF 29" TROUGH

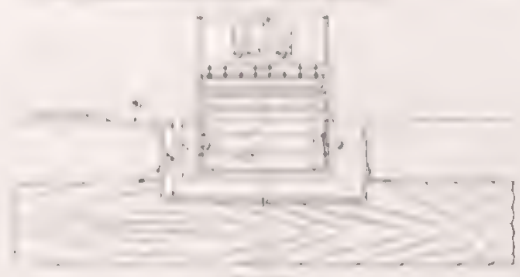
EXHIBIT "A"

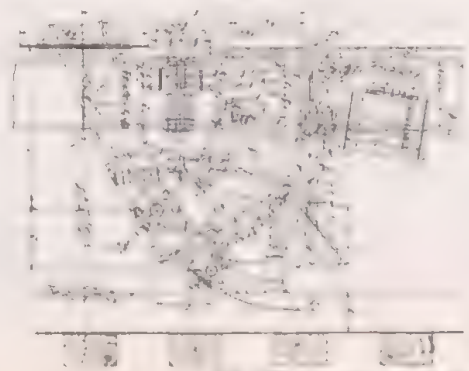


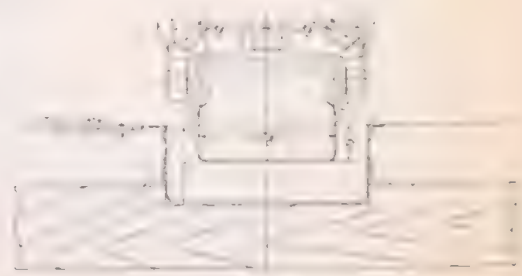
NEW YORK CENTRAL LINES

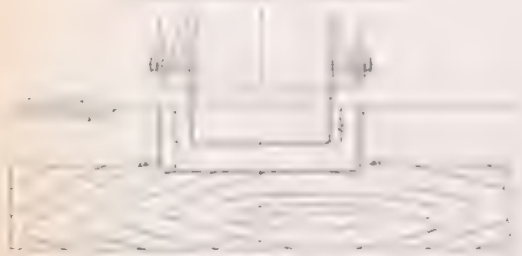












NEW YORK CENTRAL LINES.

Difference in Depths of Water at Adjacent Stations from Hook Guage Readings

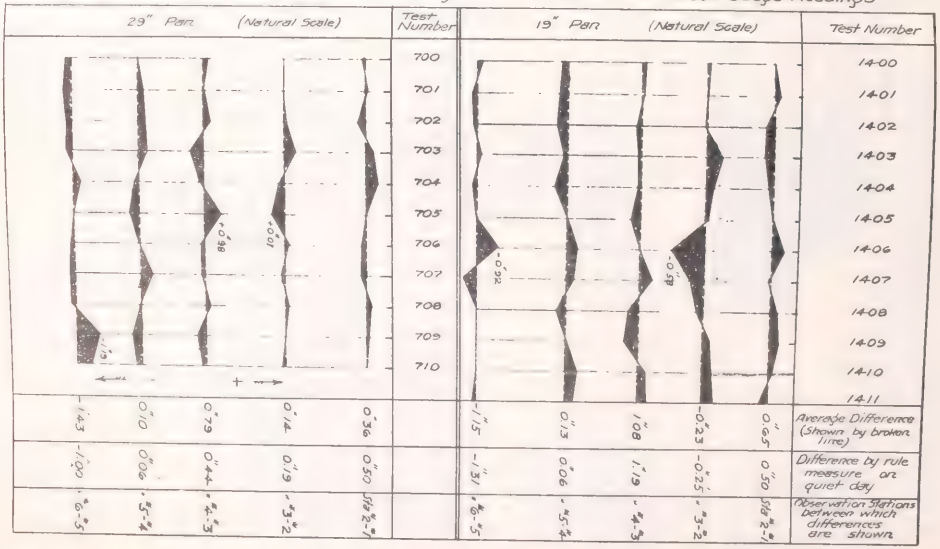
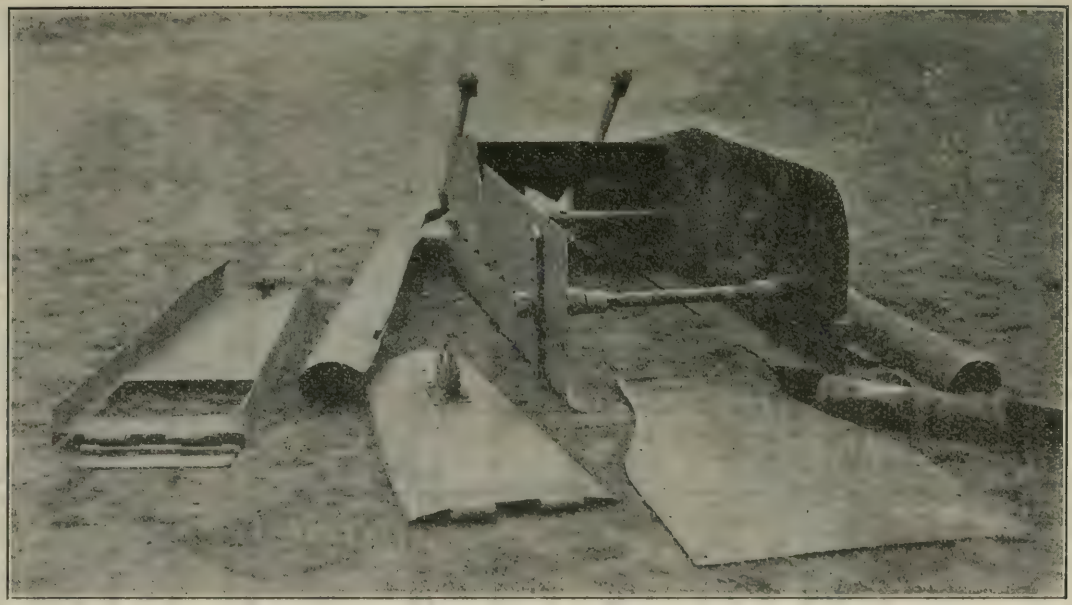


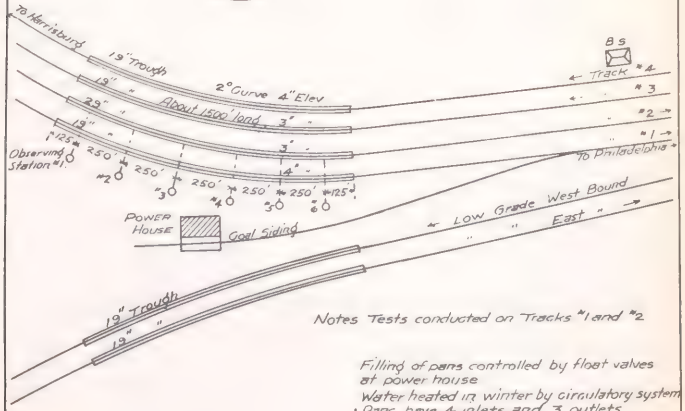
EXHIBIT "B"

The distance shaded area extends above or below dotted line shows the actual variation between the measurements for one test and the average for those shown, which were selected at random.



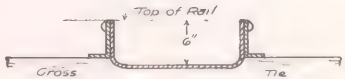
Reservoir on top of hill 90' pressure at Power House

P.R.R. WATER STATION ATGLEN PA

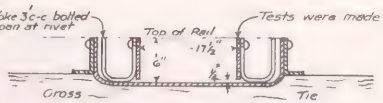


Notes Tests conducted on Tracks #1 and #2

Filling of pans controlled by float valves at power house
Water heated in winter by circulatory system
Pans have 4 inlets and 3 outlets



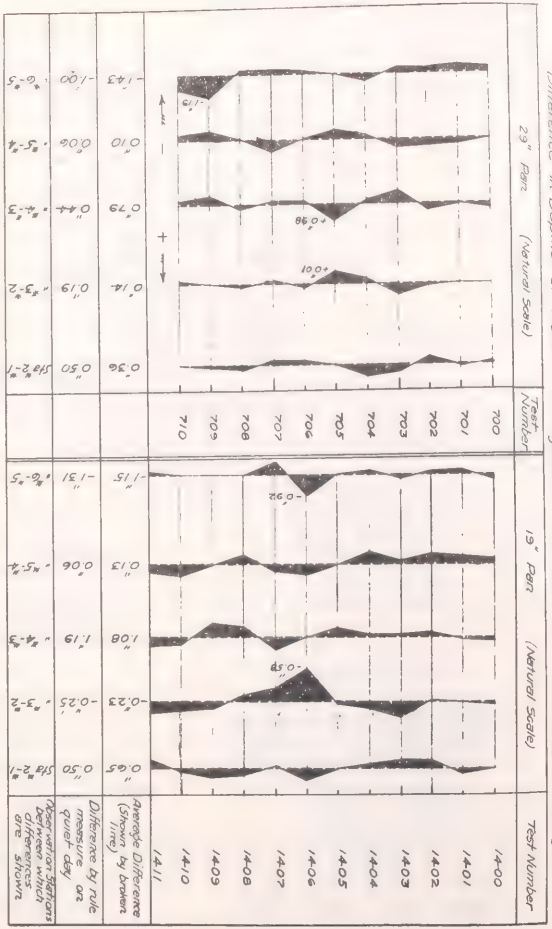
SECTION OF 19" TROUGH



SECTION OF 29" TROUGH

EXHIBIT "A"

Difference in Depths of Water at Adjacent Stations from Hook Gauge Readings



The distance shaded area extends above or below dotted line shows the actual variation between the measurements for one test and the average for those shown, which were selected at random.

EXHIBIT "B"

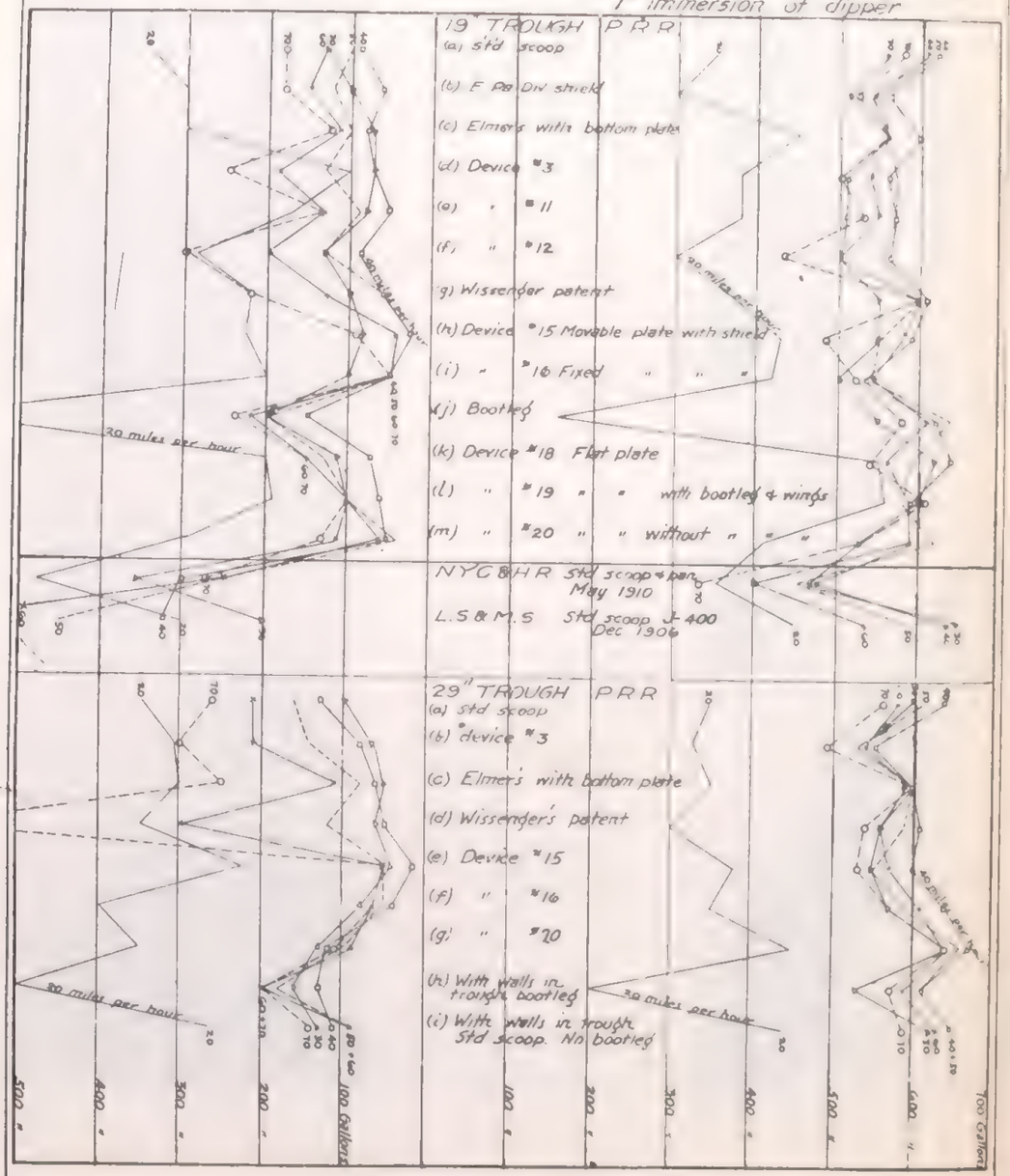

Gallons wasted per 1000' per 1"
Gallons into tender per 1000' scooped per 1" immersion of dipper
19" TROUGH PRR
(a) Std scoop
(b) E Pa Div shield
(c) Elmer's with bottom plate
(d) Device #3
(e) " #11
(f) " #12
(g) Wissenger patent
(h) Device #15 Movable plate with shield
(i) " #16 Fixed " " "
(j) Bootleg
(k) Device #18 Flat plate
(l) " #19 " " with bootleg & wings
(m) " #20 " " without " " "
NYC&HR Std scoop & pan May 1910
L.S&M.S Std scoop J-400 Dec 1906
29" TROUGH PRR
(a) Std scoop
(b) device #3
(c) Elmer's with bottom plate
(d) Wissenger's patent
(e) Device #15
(f) " #16
(g) " #20
(h) With walls in trough bootleg
(i) With walls in trough Std scoop. No bootleg
30 miles per hour
40 miles per hour
100 Gallons

EXHIBIT "C"

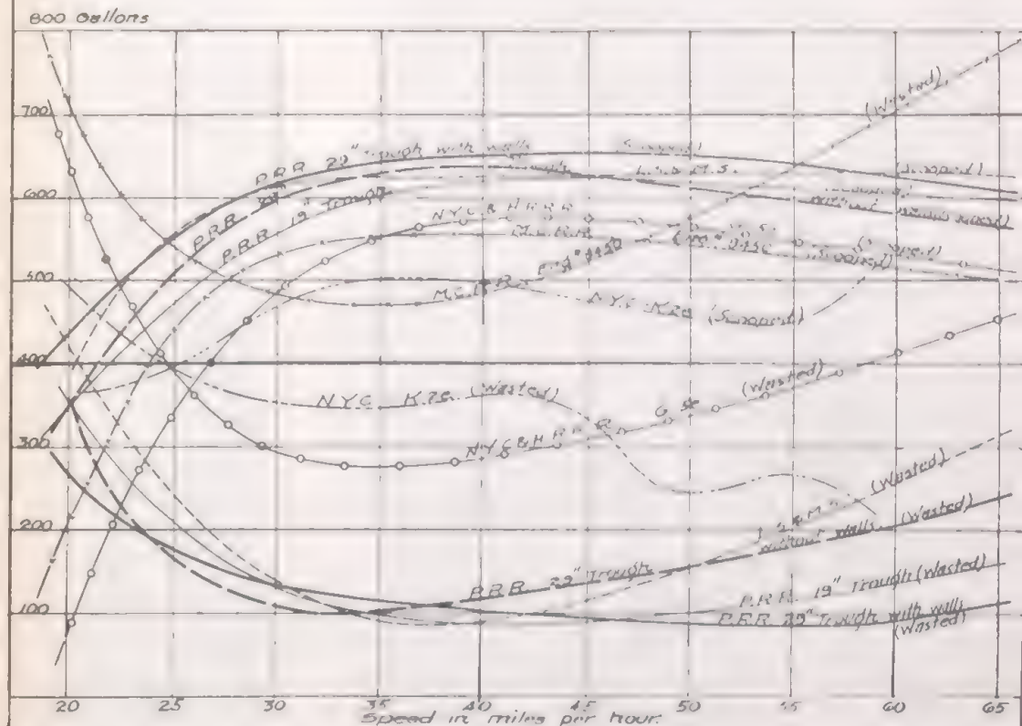


Diagram shows gallons scooped and wasted per 1000 ft. per inch of immersion of dipper, at various speeds.

P.R.R. Tests made at Atglen, Pa. 1910 with standard balanced scoop, and troughs as shown.

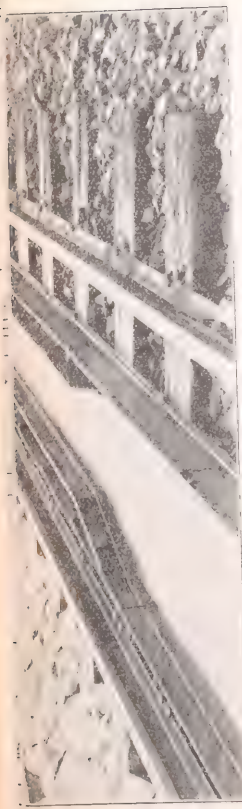
L.S&M.S tests made at Collinwood, Ohio, Apr. 1907. - L.S. Scoop

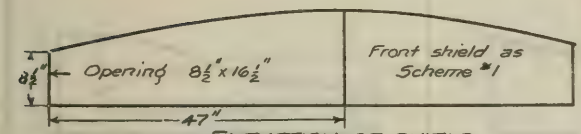
M.C.R.R. " " " " " " " - M.C. "

NYC&HRRR. (G-5e) " " " " " " - NYC "

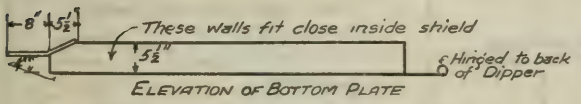
" (K-2a) made at Herkimer, N.Y. 1910 - NYC. " and 27" standard trough

EXHIBIT "D"

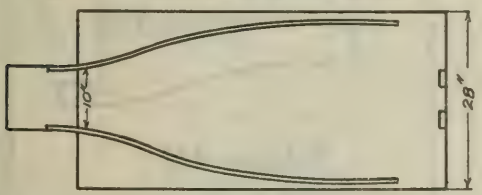




ELEVATION OF SHIELD



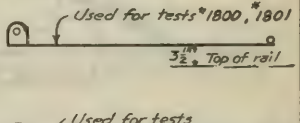
ELEVATION OF BOTTOM PLATE

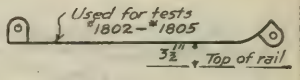


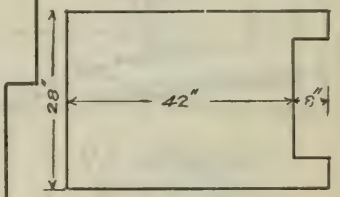
PLAN OF BOTTOM PLATE

Scheme #15

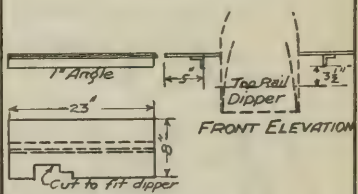
Plate is lowered to 1¾" above top of rail by dipper and auxillary shaft in rear





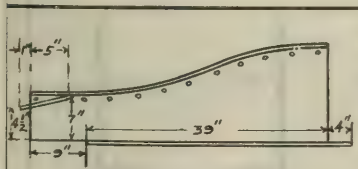


Scheme #18



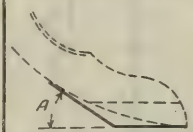
Scheme #19.

Same as #18 except winds were bolted on sides of dipper as shown and leather lining called a "bootleg" was used in scoop.



Scheme #16

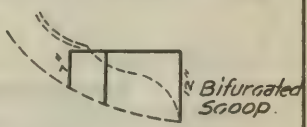
Same as #12 except center diaphragm removed and bottom plate put on also deflector put in rear end.



Gal Iron sheet on bottom of Dipper.

Cross slit in dipper. This extends entirely across.

Tried with and without director on bottom of dipper.



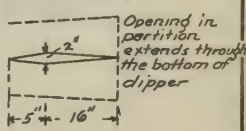
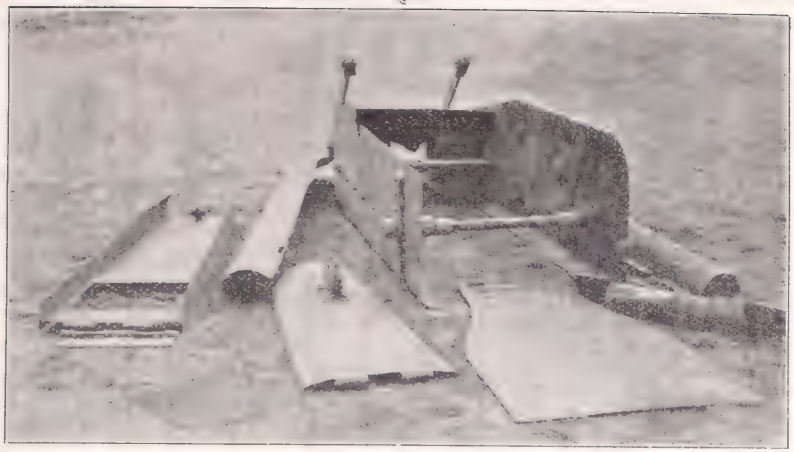
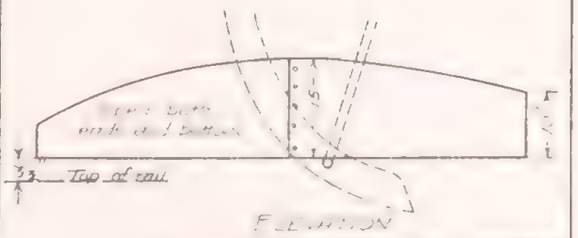


EXHIBIT "H"





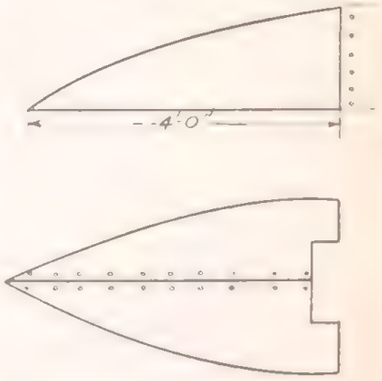
ELEVATION

PLAN

Scheme #1

Eastern Pa Div Device

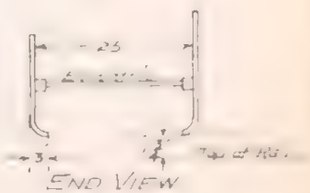
Sides vertical, movable gates with bottom edge curved in and turning away to sides, were tried in some tests



Scheme #3

Using same front shield as #1

ELEVATION



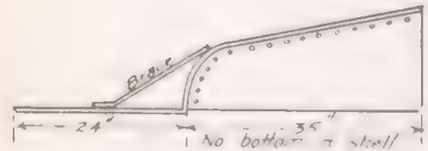
END VIEW

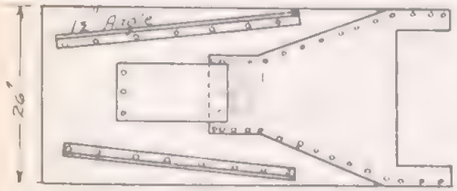
PLAN

Sketch of device in open position

Ehmer's Device

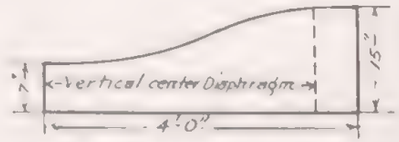
EXHIBIT "F"



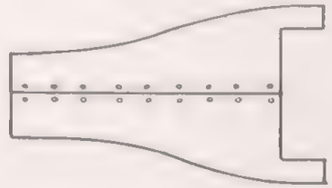


Scheme #11

Same front shield as #1

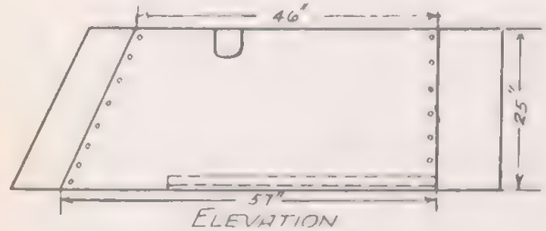


Open both ends and bottom

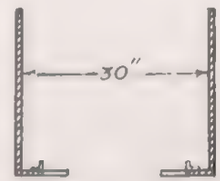


Scheme #12

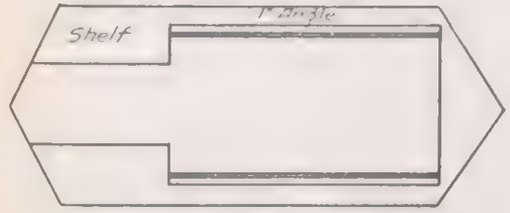
Same front shield as #1



ELEVATION



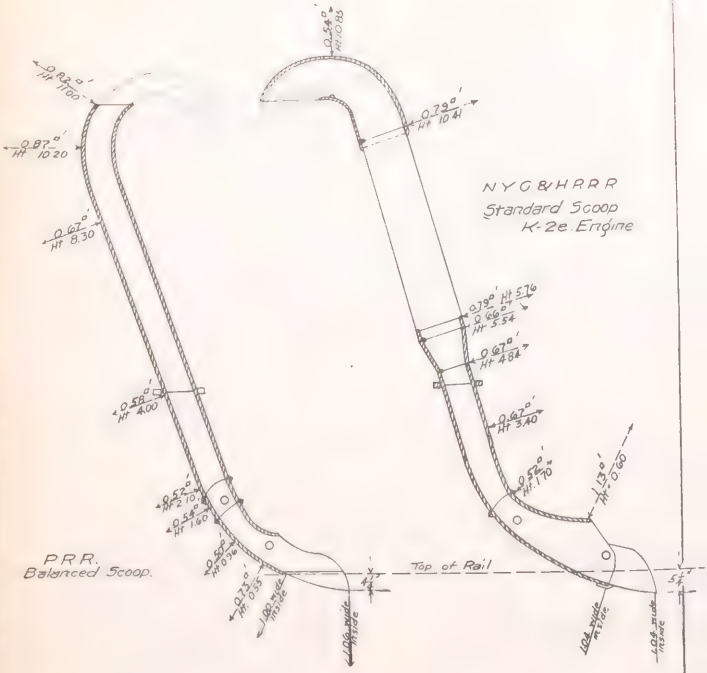
SECTION



Plan of bottom showing shelf to catch splash

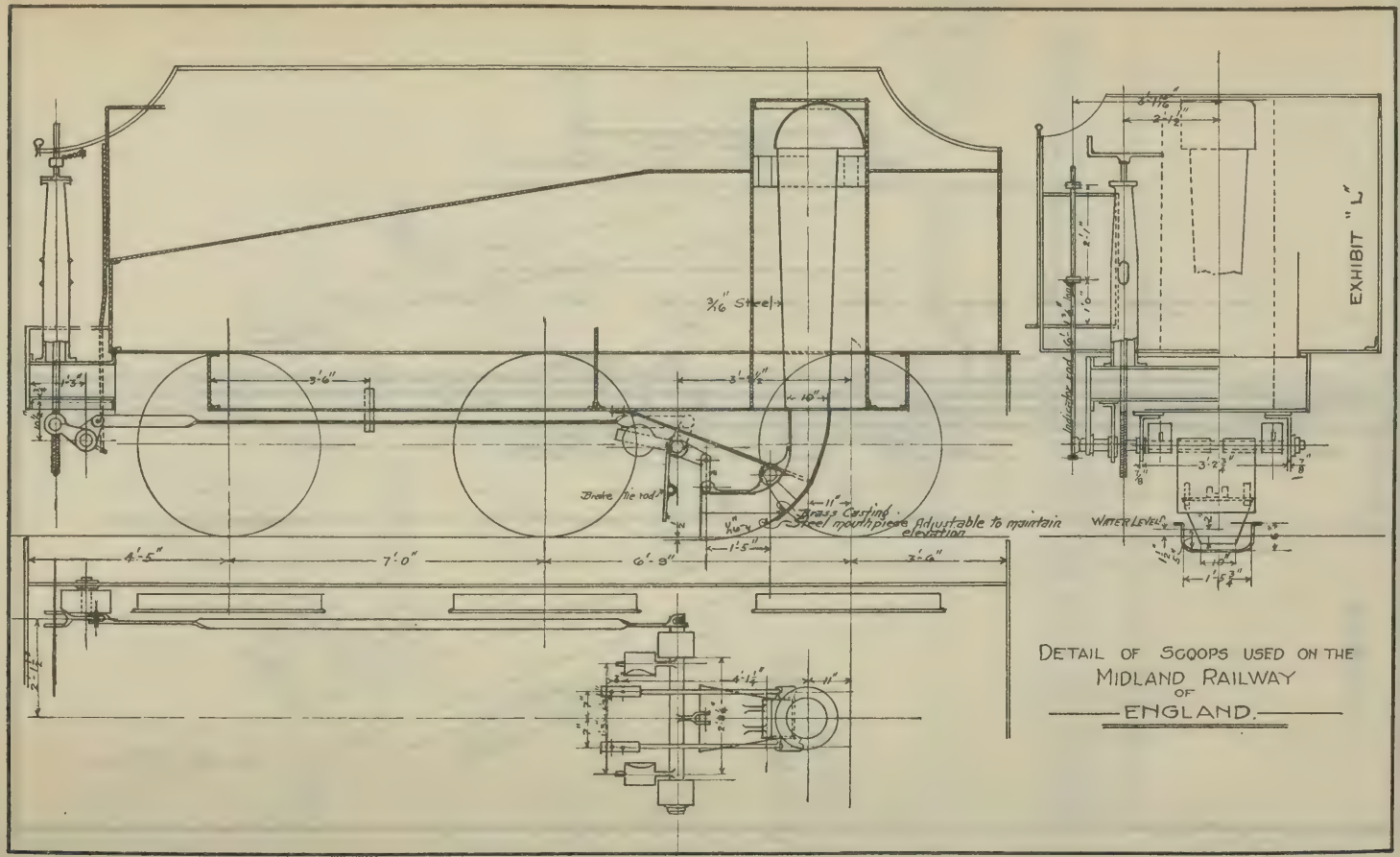
Wissender Device
(Patented)

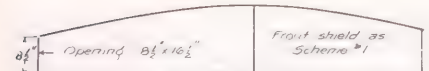
EXHIBIT "G"



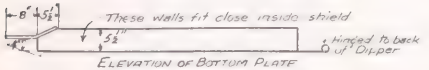
Heights shown refer to point at back of section and give vertical distance above point of dipper. The broken lines with arrows show areas of sections graphically. Areas are given in square feet.

EXHIBIT "I"

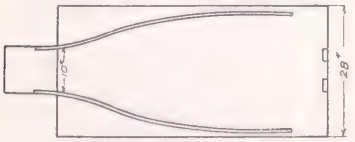

3/16" Steel
3'-6"
3'-6"
10"
Brake tie rod
11"
Brass Casting
Steel mouthpiece Adjustable to maintain elevation
4'-5"
7'-0"
6'-3"
1'-5"
3'-0"
4'-1½"
11"
EXHIBIT "L"
WATER LEVEL
DETAIL OF SCOOPS USED ON THE MIDLAND RAILWAY OF ENGLAND.



ELEVATION OF SHIELD



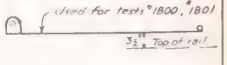
ELEVATION OF BOTTOM PLATE

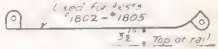


PLAN OF BOTTOM PLATE

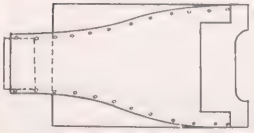
Scheme #15

Plate is lowered to 1⅜" above top of rail by dipper and auxiliary shaft in rear





Scheme #18

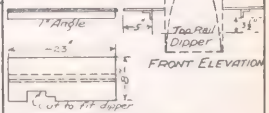


Scheme #16

Same as #12 except center diaphragm removed and bottom plate put on also deflector put in rear end

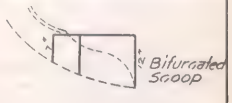
Cross slit in dipper. This extends entirely across.

Tried with and without director on bottom of dipper.



Scheme #19.

Same as #18 except wings were bolted on sides of dipper as shown and leather lining called a "bootleg" was used in scoop



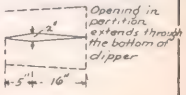
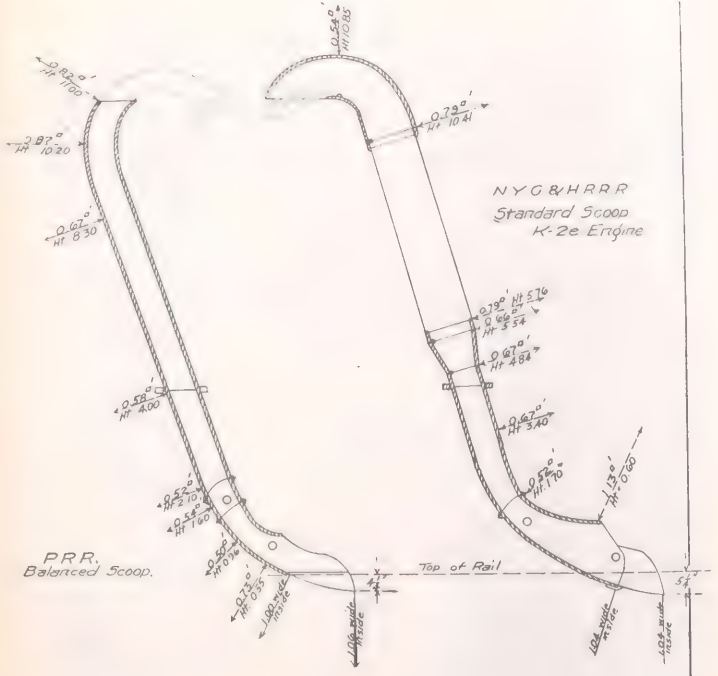
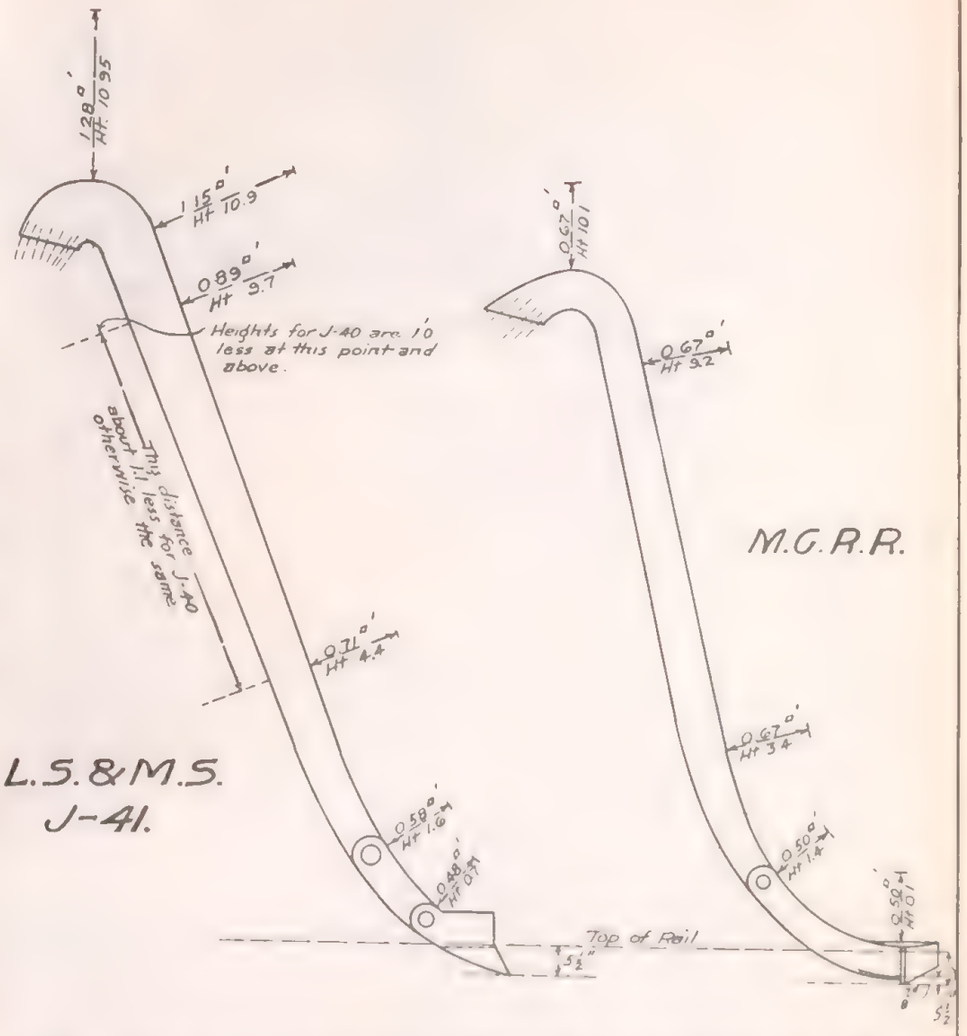


EXHIBIT "H"



Heights shown refer to point at back of section and give vertical distance above point of dipper. The broken lines with arrows show areas of sections graphically, Areas are given in square feet.

EXHIBIT "I"



Heights refer to point at back of section and give vertical distance above point of dipper. The broken lines with arrows show cross section areas, which are given in square feet, graphically.

The above sketches are copied from report of L.S.&M.S. Ry. on water scoop tests at Collinwood Apr. 1907, and the heights shown, scaled

EXHIBIT "J"

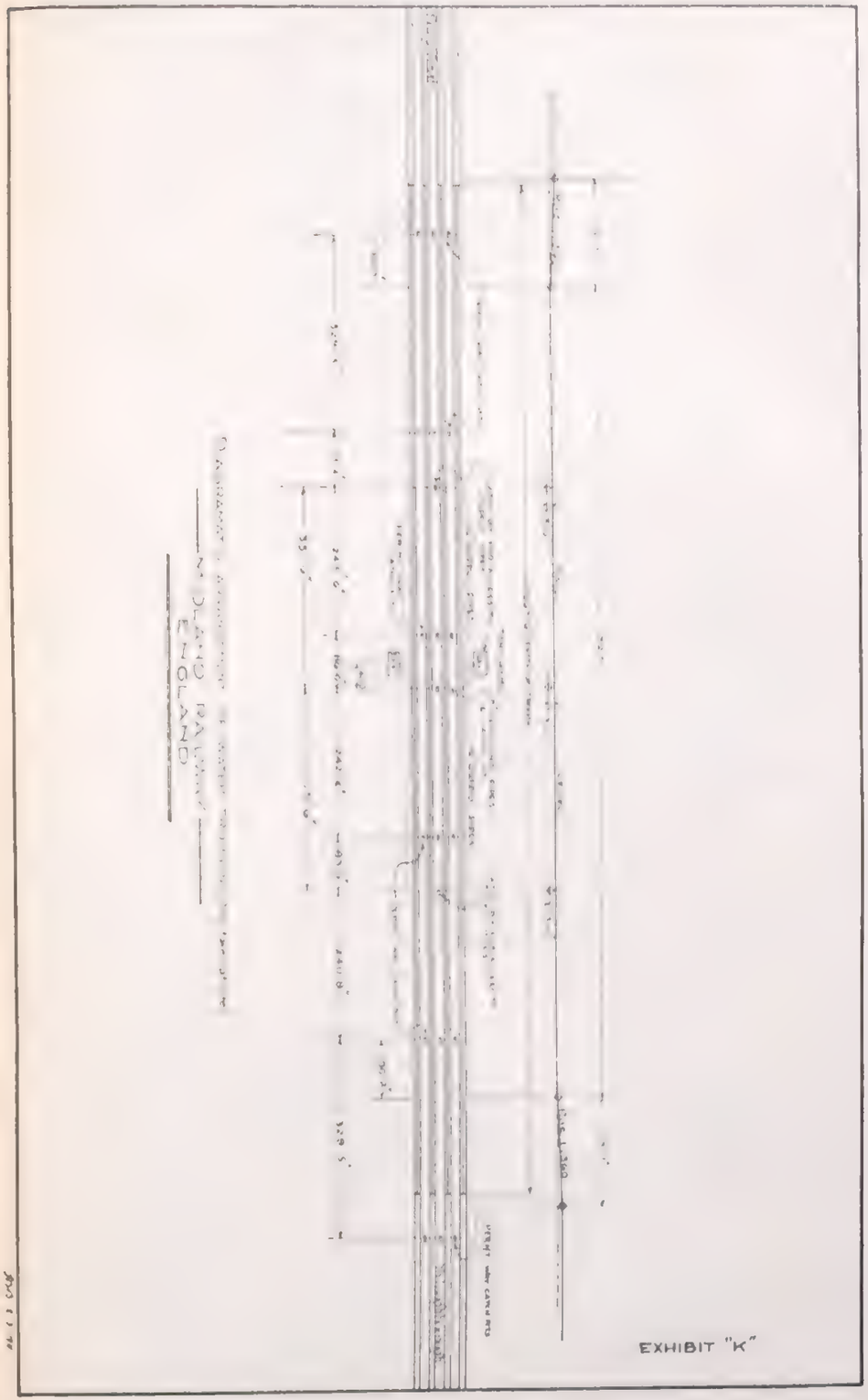


EXHIBIT "K"

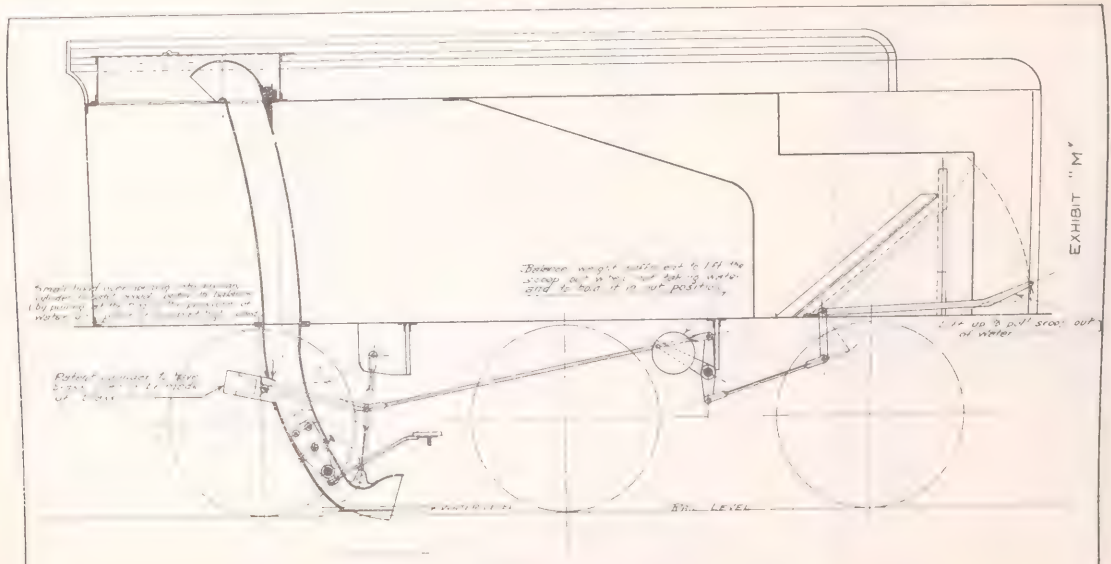
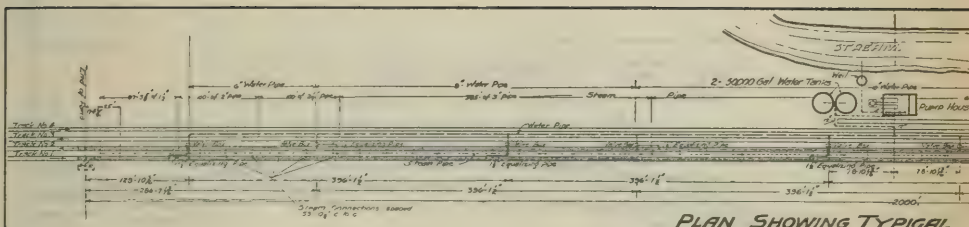
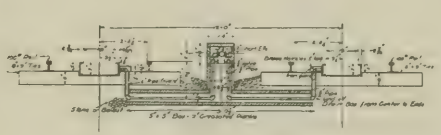


EXHIBIT "M"
Balance weight rails out to lift the scoop as it is not taking water and to hold it in out position.
Rotary scraper to keep
RAIL LEVEL

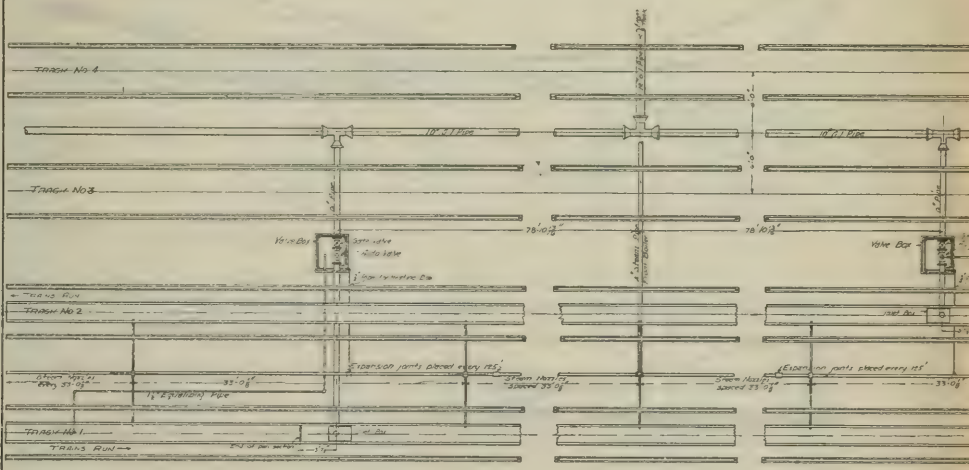
DETAIL OF SCOOPS USED ON THE
GREAT NORTHERN RY
ENGLAND
Scale 1/2 = 1-0



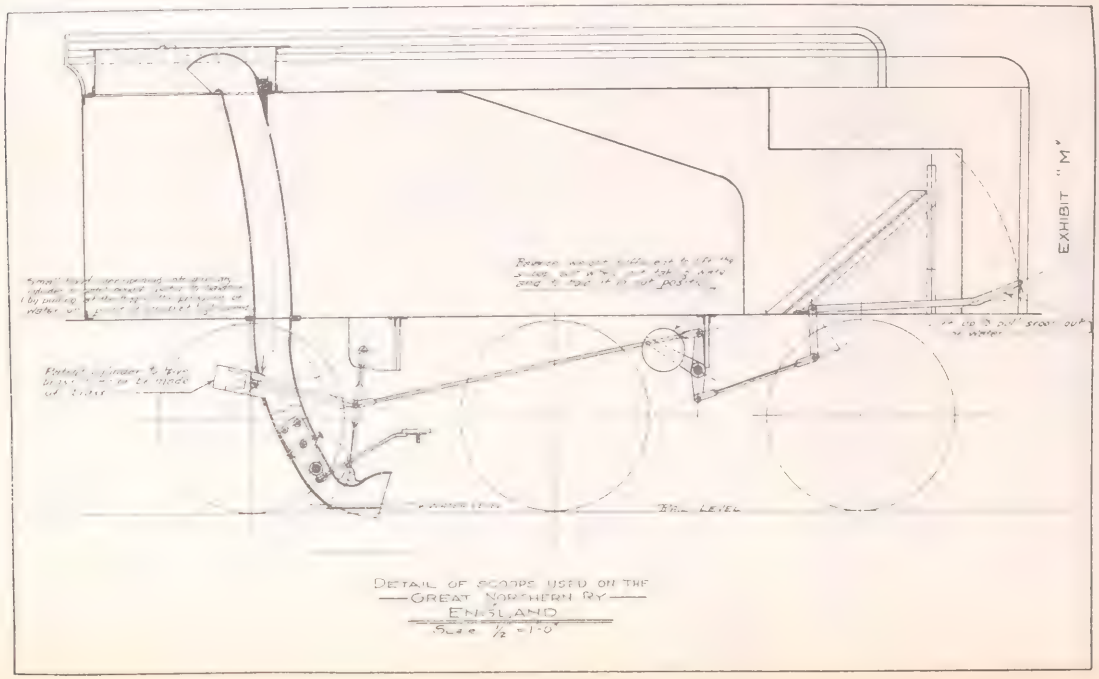
PLAN SHOWING TYPIGAL



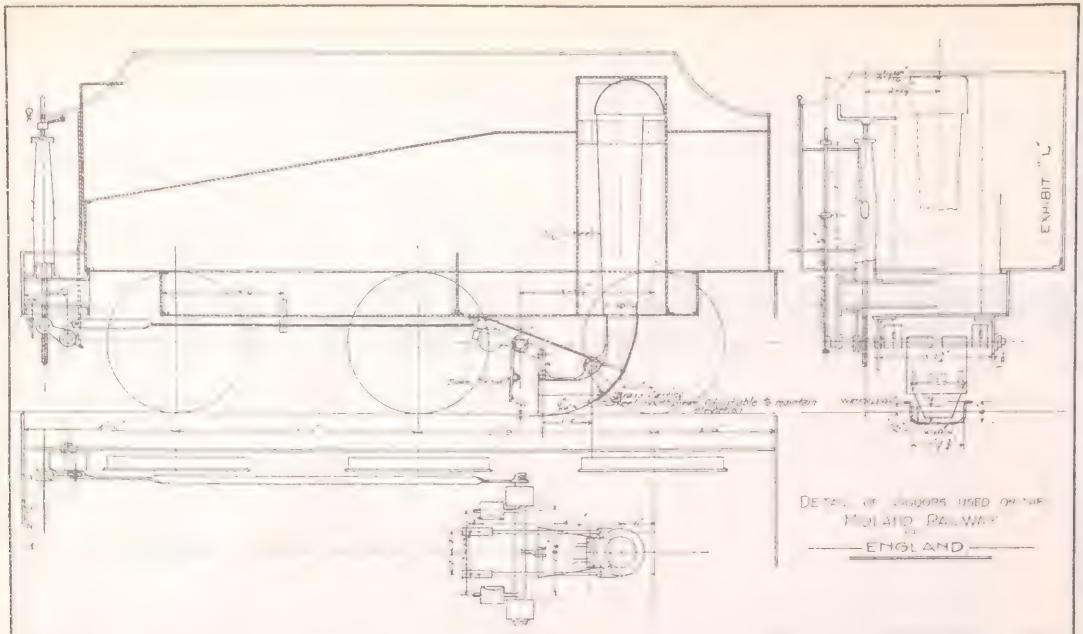
STEAM PIPE CONNECTIONS.



PLAN OF STEAM AND WATER PIPE CONNECTIONS.



DETAIL OF SCOOPS USED ON THE
GREAT NORTHERN RY
ENGLAND
SCALE 1/2 = 1'-0"



DETAIL OF SCOOPS USED ON THE
MIDLAND RAILWAY
ENGLAND

TESTS WITH DIFFERENT DEPTHS
OF IMMERSION STANDARD SCOOP
PENNSYLVANIA RAILROAD.
19 INCH TRACK TANK.

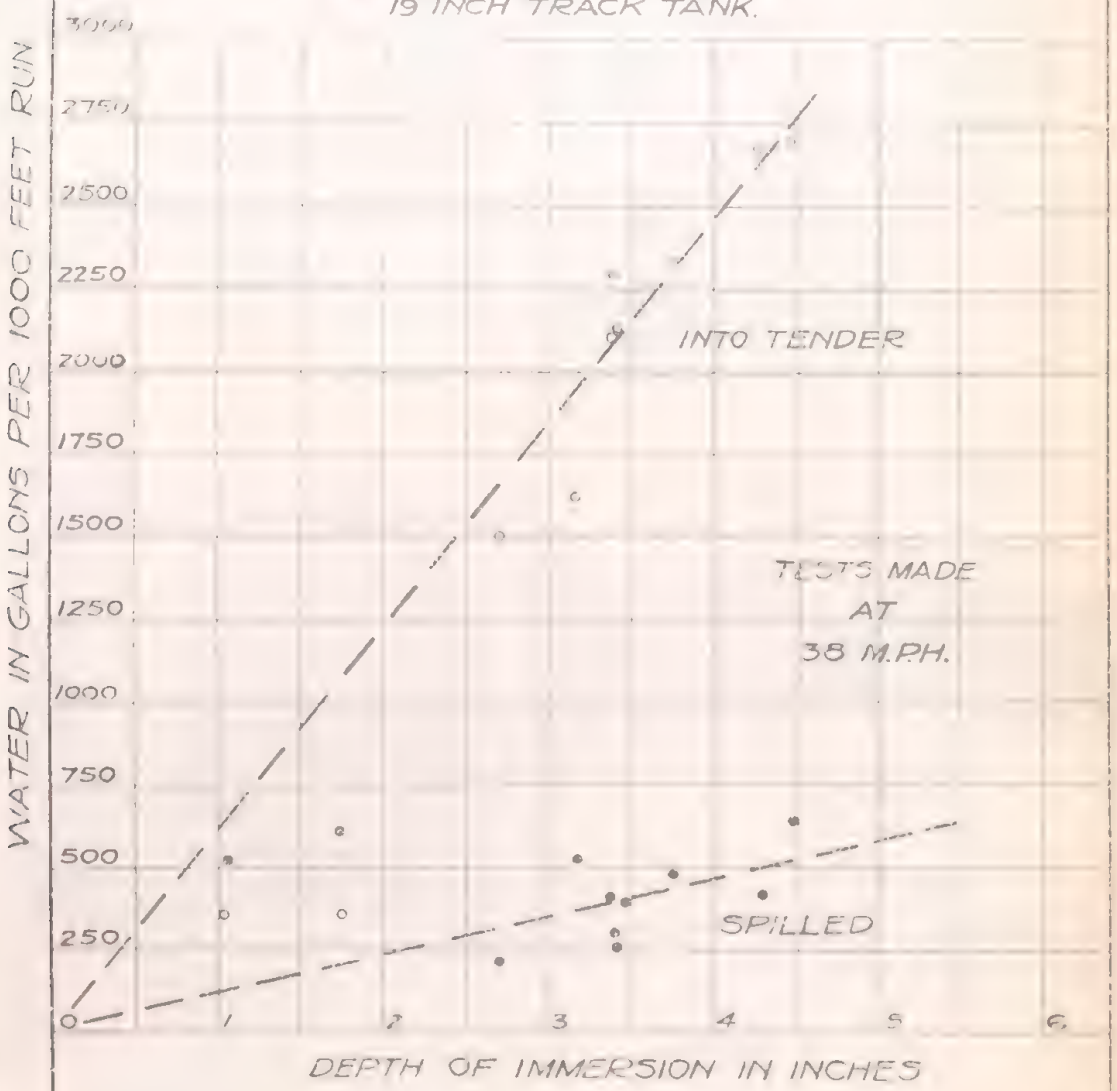


EXHIBIT "N"

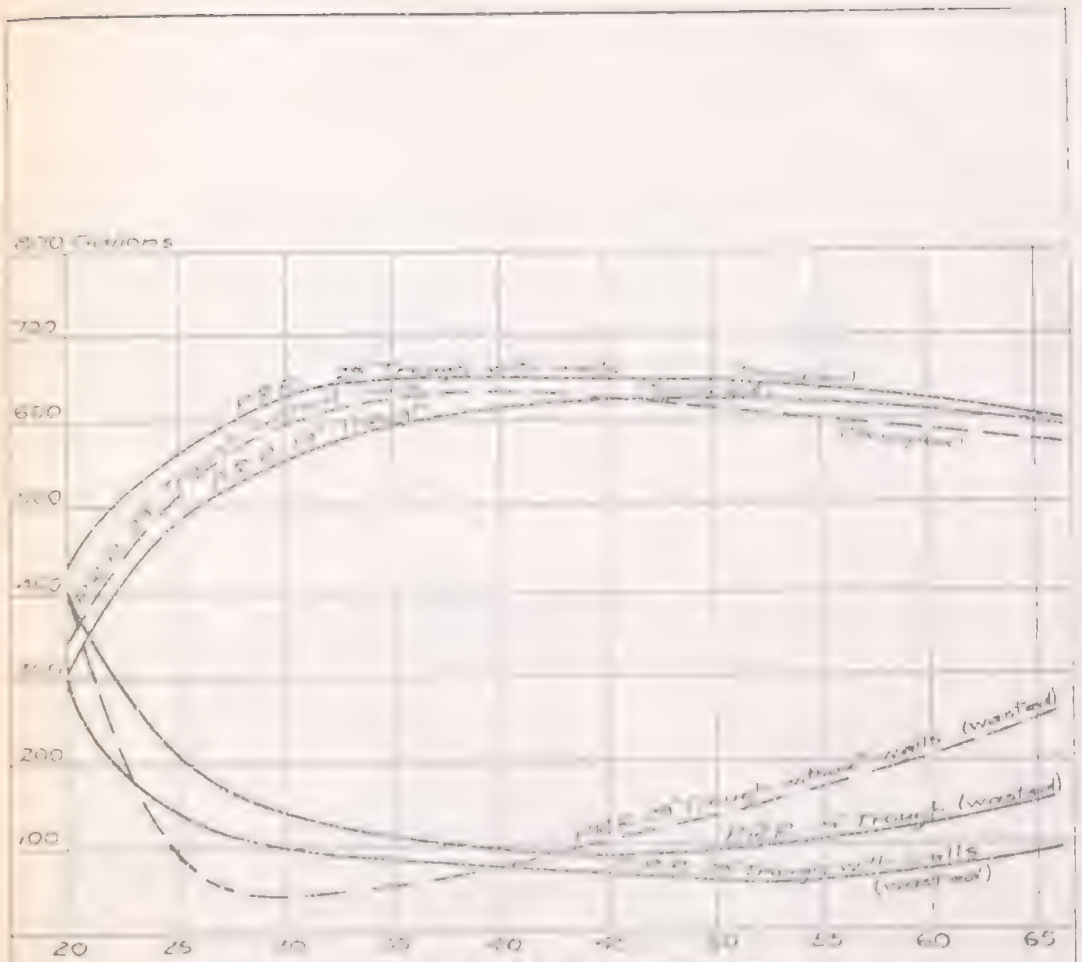
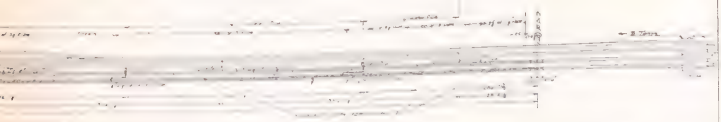
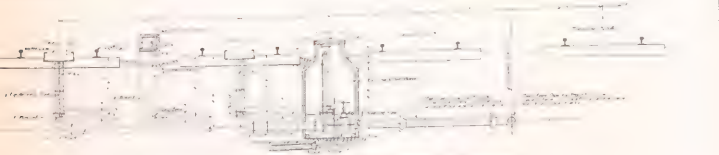


Diagram showing gallons scooped and wasted per 1000 feet per inch of immersion of dipper, at various speeds.

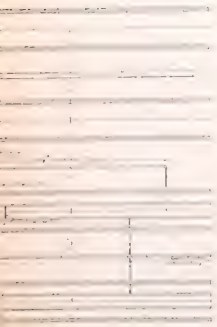
PRR Tests made at Altoona Pa 1910 with standard balanced scoop and troughs as shown

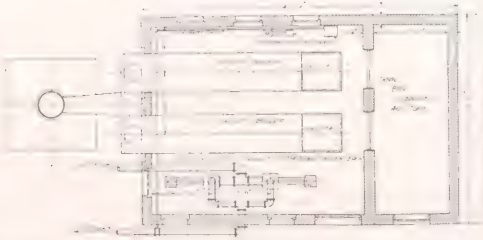
EXHIBIT "O"

WCP

LAYOUT.



CROSS SECTION OF TRACKS-SHOWING PIPING AND VALVES.

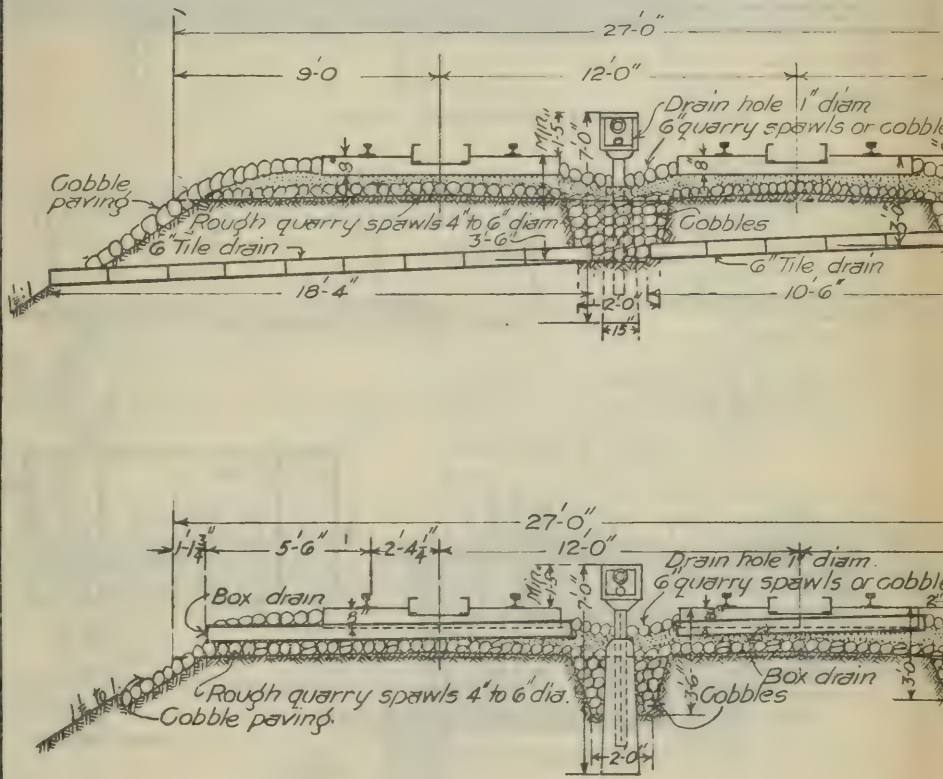




PUMP HOUSE.

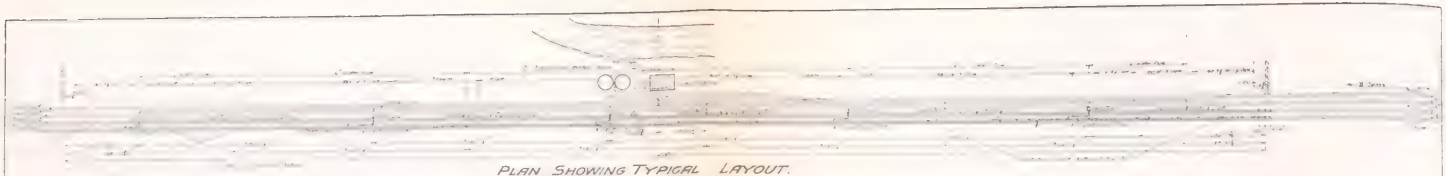
NEW YORK CENTRAL LINES

STANDARD TRACK TANK
DEEP HEATING SYSTEM



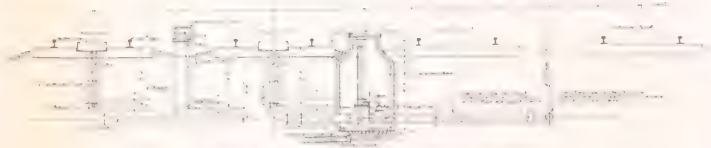
GROSS SECTIONS TRACK DRAIN

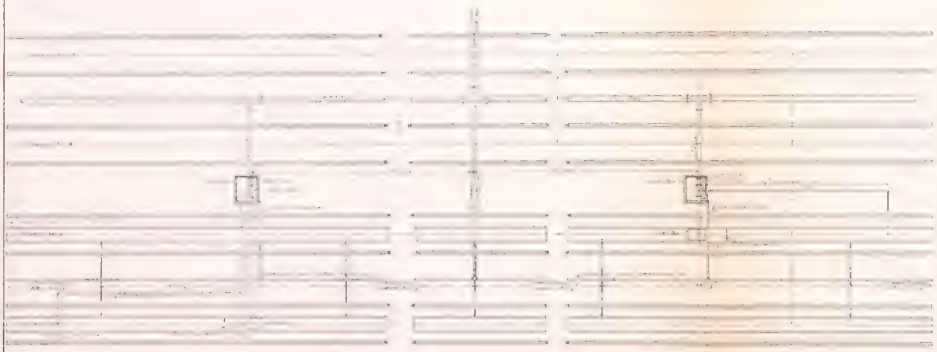
TRACKS TO BE LAID WITH 100# 6" RAIL

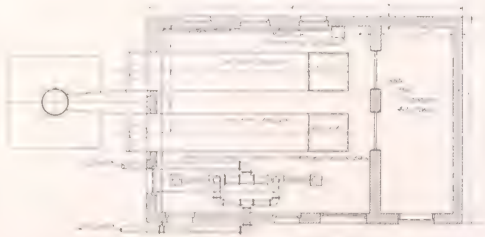


PLAN SHOWING TYPICAL LAYOUT.

STEAM PIPE CONNECTIONS.

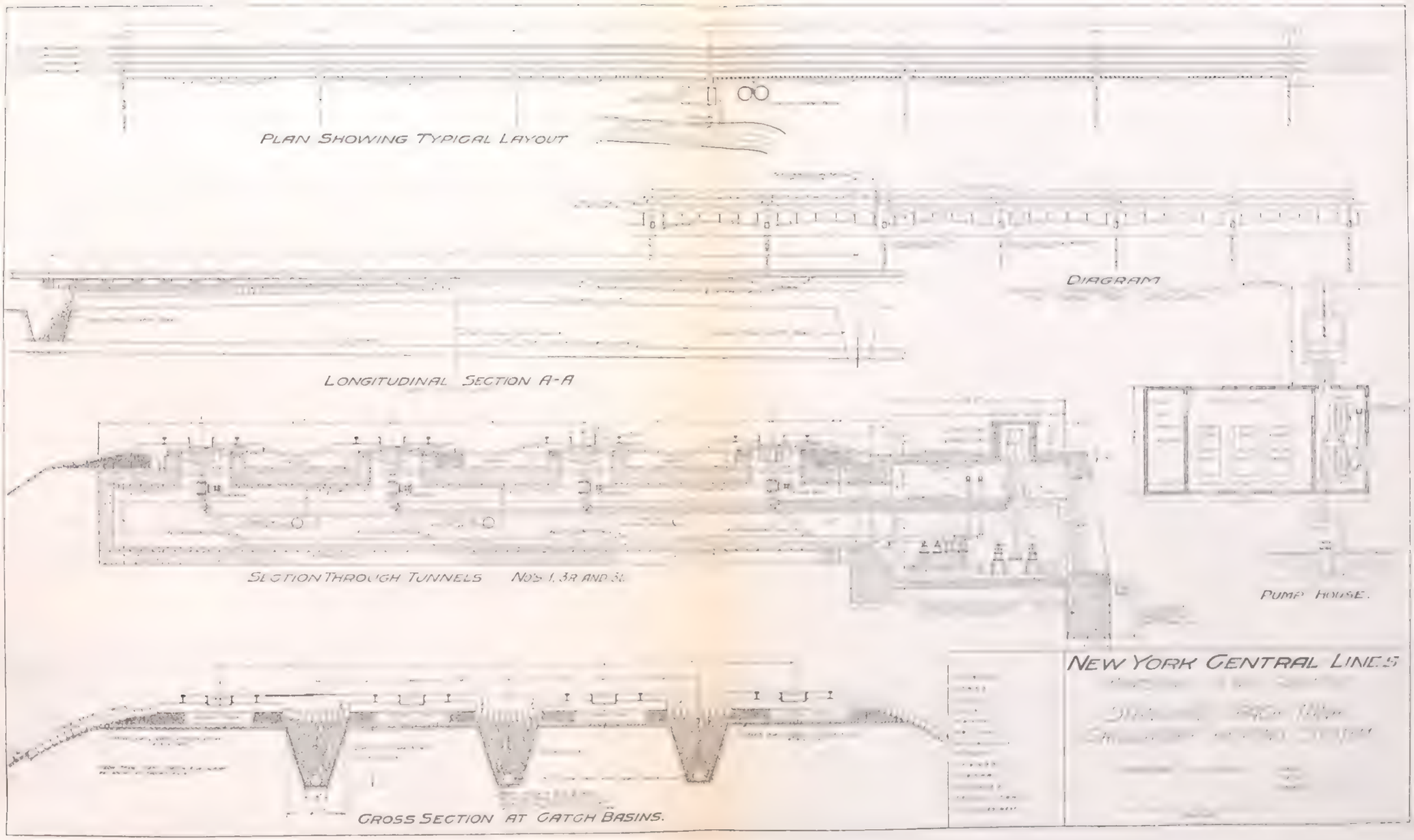


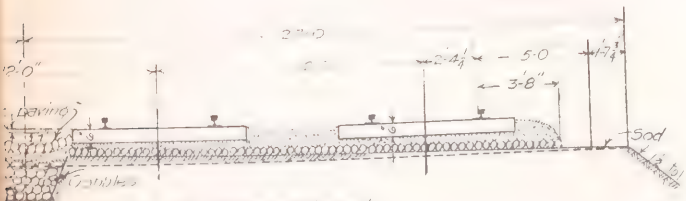
CROSS SECTION OF TRACKS—SHOWING PIPING AND VALVES.

PLAN OF STEAM AND WATER PIPE CONNECTIONS.

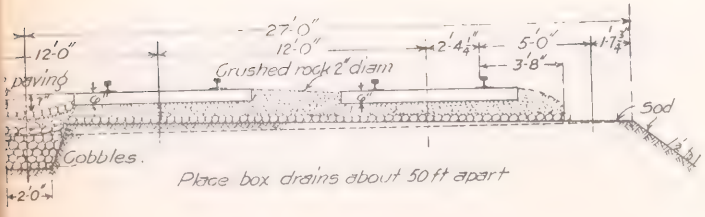


PUMP HOUSE.

NEW YORK CENTRAL LINES


PLAN SHOWING TYPICAL LAYOUT
DIAGRAM
LONGITUDINAL SECTION A-A
SECTION THROUGH TUNNELS NOS. 1, 3R AND 3L
PUMP HOUSE.
NEW YORK CENTRAL LINES
GROSS SECTION AT CATCH BASINS.





IAGE.

NYC & HRRR
LS & MS RY
MC RR
GGG & STL RY
B & A RR
P & LE RR
NYC & STL RR
RUTLAND RR
LE & W RR
C I & S RR
GIN. NOR. RR
T & OC RY - Z & W RY
NYC LINES WEST

NEW YORK CENTRAL LINES.

MAINTENANCE OF WAY COMMITTEE.

STANDARD TRACK TANKS

DRAINAGE FOR

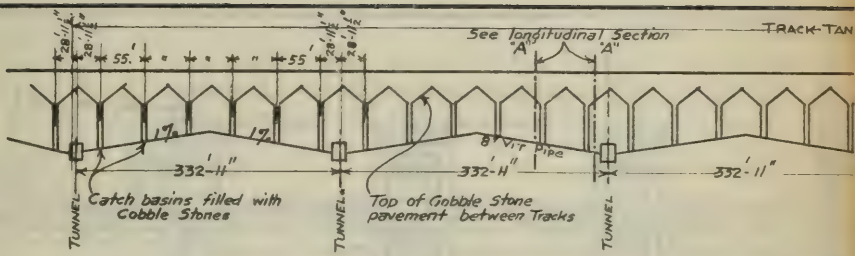
DIRECT HEATING SYSTEM

Recommended by Committee Date

File No.

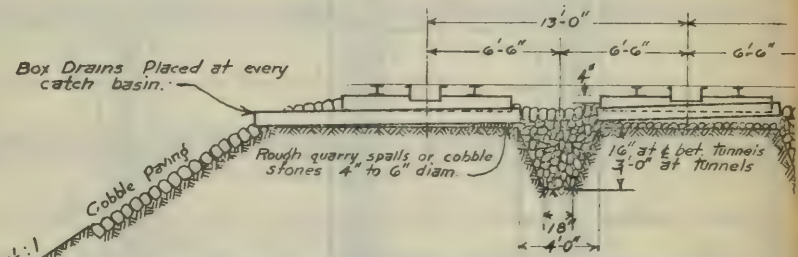
Issue No

Chairman

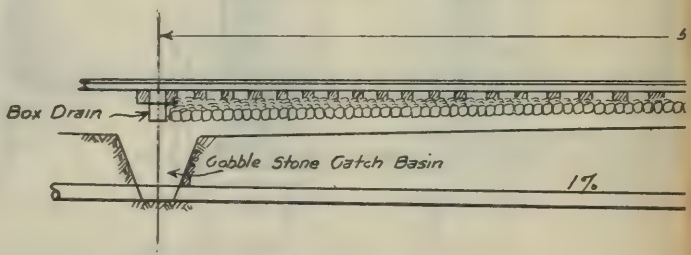


DIA

SHOWING ARRANGEMENT

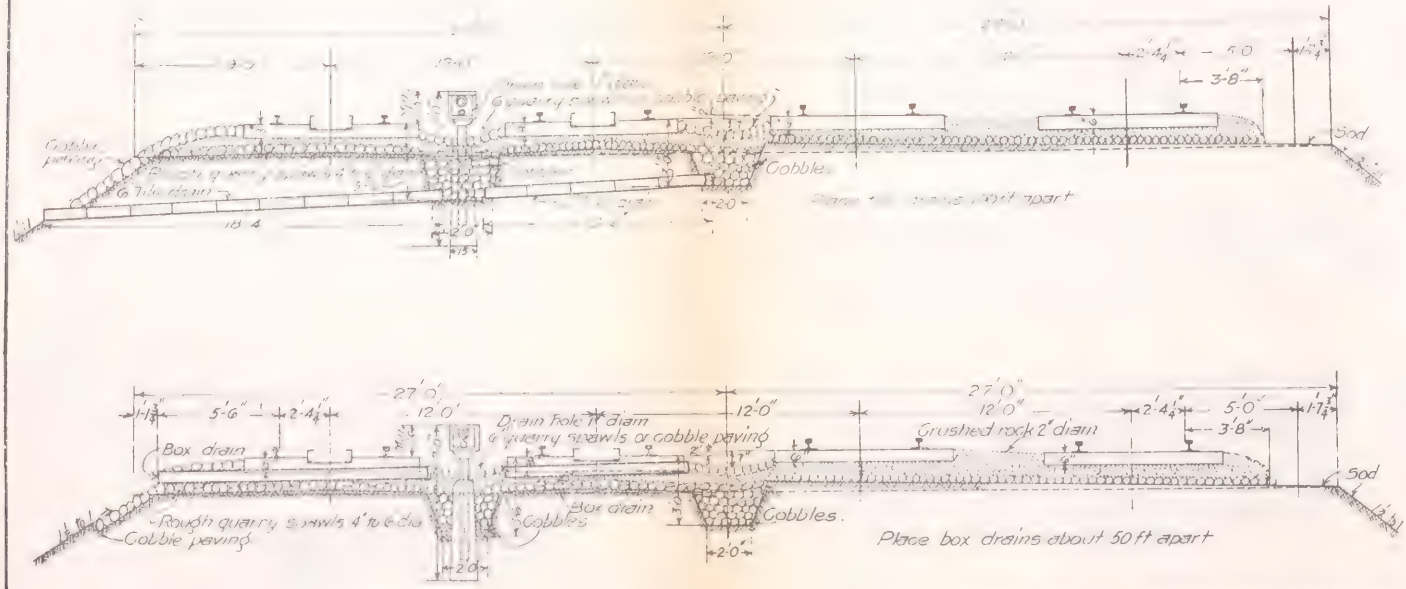


GROSS SECTION A



LONGITUDINAL SECTION

(SEE DIAGRAM.)



GROSS SECTIONS TRACK DRAINAGE.

TRACKS TO BE LAID WITH 100# 6" RAIL

NYC&HRRR
LS&MS RY
M.C.R.R
CC.C.&St.L.RY
B&A.R.R
P.R.R.R
NYC&St.L.R.R
RUTLAND.R.R
L.E.&W.R.R
C.I.&S.R.R
GIN.NOR.R.R
T&O.C.RY-Z&W.RY
NYC.LINES WEST

NEW YORK CENTRAL LINES.

MAINTENANCE OF WAY COMMITTEE.

STANDARD TRACK TANKS

DRAINAGE FOR

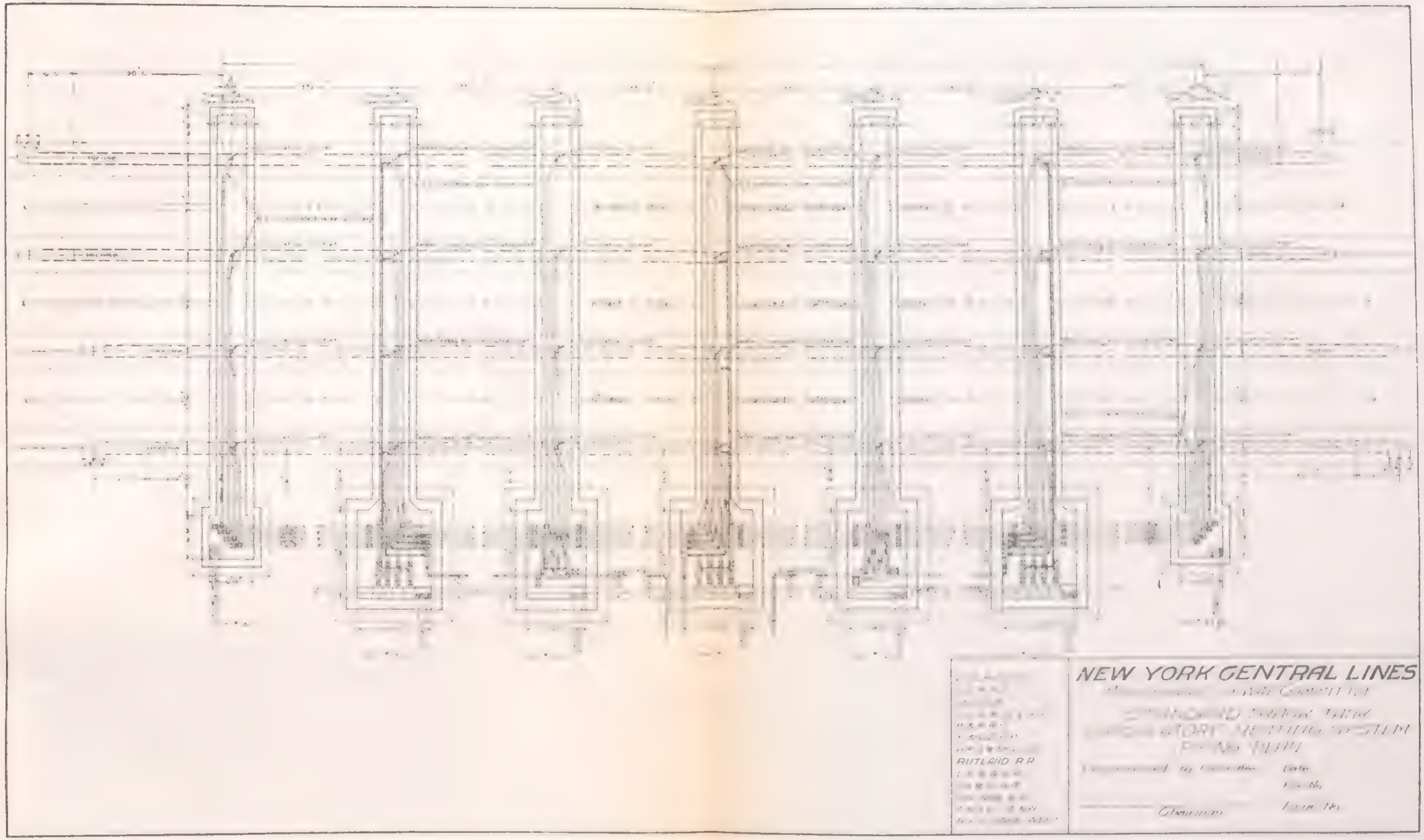
DIRECT HEATING SYSTEM

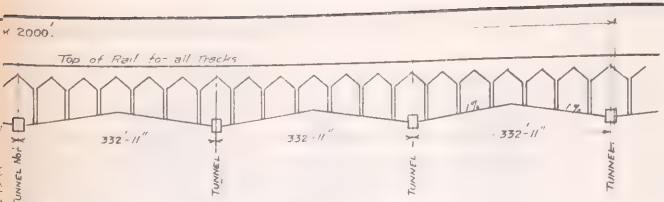
Recommended by Committee Date

File No.

Issue No

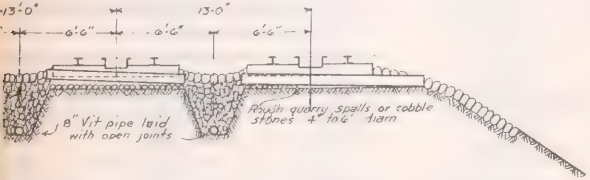
Chairman


RUTLAND R R
NEW YORK CENTRAL LINES

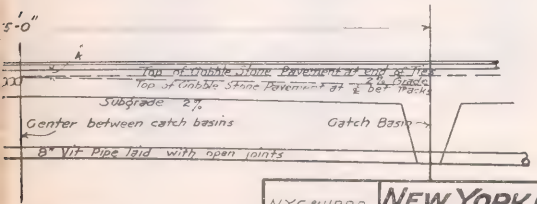


SRAM

OF DRAIN PIPES AND CATCH BASINS



AT CATCH BASINS


5'-0"
Top of Cobble Stone Pavement at end of Ties
Top of Cobble Stone Pavement at ℄ bet Tracks
Subgrade 2%
Center between catch basins
Catch Basin
8" V.it Pipe laid with open joints

A-A

N.Y.C. & H.R.R.R. L.S. & M.S. Ry. M.C.R.R. C.C.C. & St.L. Ry. B. & A.R.R. P. & L.E.R.R. N.Y.C. & St.L.R.R. Rutland R.R. L.E. & W.R.R. C.I. & S.R.R. Gin. Nor. R.R. T. & O.C. Ry. I. & W. N.Y.C. Lines West	**NEW YORK CENTRAL LINES.** MAINTENANCE OF WAY COMMITTEE STANDARD TRACK TANKS DRAINAGE FOR CIRCULATORY HEATING SYSTEM Recommended by Committee Date File No Issue No Chairman.

The test equipment was very elaborately and scientifically prepared to insure the results being as accurate as possible. The test train consisted of an Atlantic Type engine weighing 88 tons and tender weighing, loaded, 66 tons, followed by a dynamometer car, to which was attached a tender with special arrangements for conducting the tests. This tender was loaded with about 20,000 lbs. of iron, boxed in, corresponding to three-fourths of the coal load. It was equipped to operate the scoop by air, those in regular service on the Pennsylvania Railroad being worked by hand.

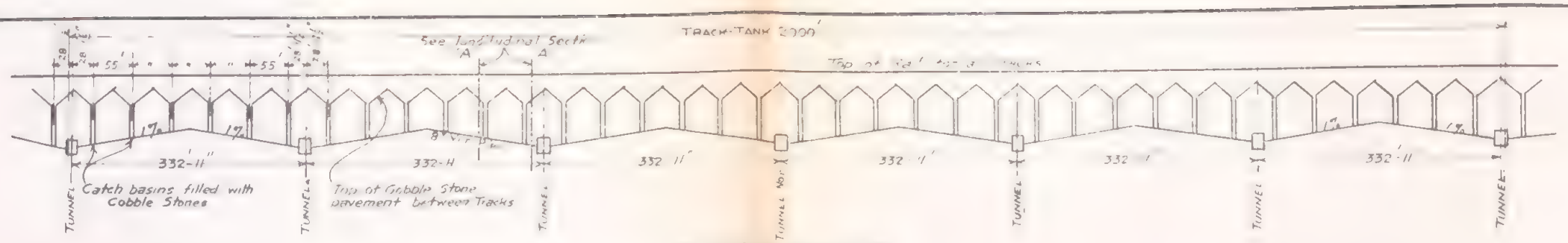
An electric contact on the scoop lever records in the dynamometer car, when the scoop is lowered and raised. Glass tubes set in ¾-in. pipes, which are planed away and graduated, show the heights of water in the tender at two diagonal corners. The tender was carefully calibrated by measuring the water contained at various readings of the front and rear gages. A disk valve and down spout in bottom of tender enables the water scooped to be returned to the trough when the train is backing for a new test. Underneath the tender an auxiliary rocker shaft is installed to help operate some of the devices experimented with.

The dynamometer car record was used to show the speed of the train (the engineman regulates this on hand signals from the car), the time and distance scoop is lowered and the beginning and end of the trough. A draw-bar pull record, taken when scoop was in bad order and jumping, showed a variation of from 600 to 700 lbs., at a speed of 65 miles per hour. The pull was not usually obtained, as application of the brakes during scooping, to regulate the speed, would generally spoil the record.

The primary object of the investigation was the determination of the efficiency of the Pennsylvania Railroad Standard Scoop, when used with the narrow and wide pans, at various speeds, and how that efficiency could be improved by altering the design of the pans and scoops, and by the application of devices to reduce splashing and to return the splash to the troughs.

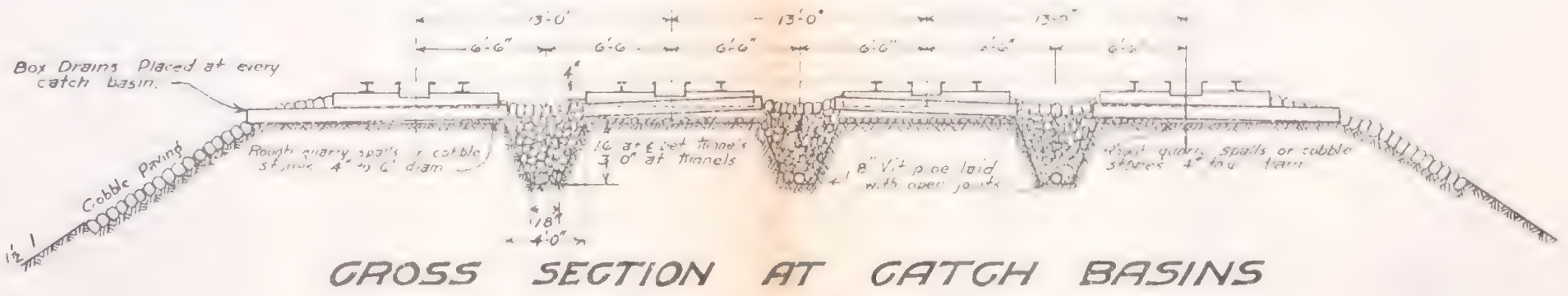
When ready to make a test, the test train was placed on a siding and the device to be tried put in place on the experimental tender. Right to use one of the tracks was then obtained, and the train backed a sufficient distance to enable it to attain the required speed on the return run. Before and after each run the train was held ten minutes to enable the water in the trough to become quiet enough for measurements. About fifteen runs were made per day. Tests were made usually at speeds of 20, 35, 50 and 65 miles per hour.

Before making a test the automatic valve supplying the pan with water was shut off. Hook gage readings of the height of the water in the trough were then taken, at points 250 ft. apart, and 125 ft. from each end, as shown on Exhibit "A." Supplementing these readings the height of the water was recorded on a paper wrapped around a cylinder, by means of a pencil operated by a float gage, the float gage being connected

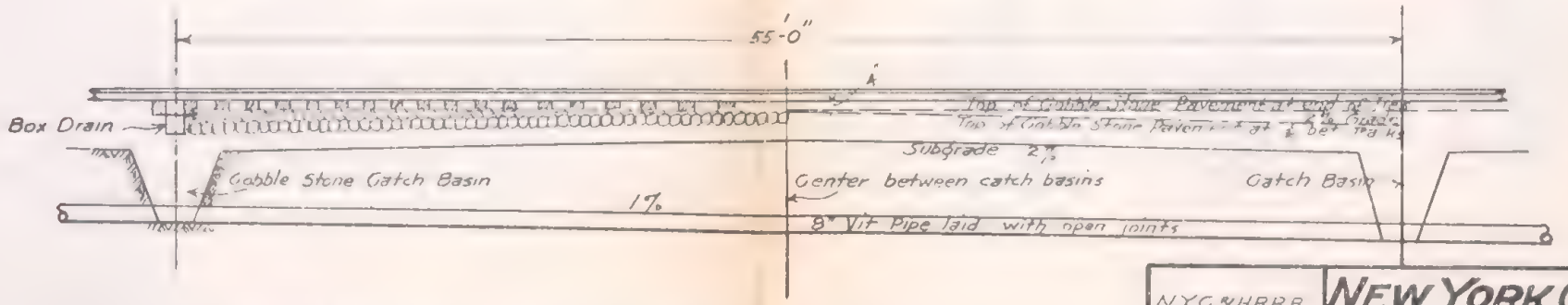


DIAGRAM

SHOWING ARRANGEMENT OF DRAIN PIPES AND CATCH BASINS



CROSS SECTION AT CATCH BASINS



LONGITUDINAL SECTION A-A

(SEE DIAGRAM.)

NYC & HRRR
LS & MS RY
M C RR
CCC & St. L RY.
B. & A R.R.
P & LE R R
NYC & STL RR
RUTLAND R R
LE & W RR
C I & S R R
CIN NOR. R R.
T & O C RY. Z & W
N.Y.C. LINES WEST

NEW YORK CENTRAL LINES.

MAINTENANCE OF WAY COMMITTEE

STANDARD TRACK TANKS
DRAINAGE FOR CIRCULATORY
HEATING SYSTEM.

Recommended by Committee Date

File No

Issue No

Chairman.

to the bottom of the troughs by a ¾-in. hose and pipe with flange and rubber gasket. Also at the second and fifth stations, the height of the water was observed by means of tube gages, set on a slope of 1 in 5, similarly connected with the troughs. A difference of one inch in height of water in trough will thus show 5 in. on gage. Readings are made simultaneously upon blasts from an air signal at the power station.

After making a test, the same measurements were taken, so that the water removed from the trough could be computed. To aid in making the water quiet, baffle boards were set across the trough to stop the flow. A very helpful feature was that these computations were made at once, thus showing up any discrepancy or unreliable result that should be discarded, and the test repeated. This also helps one to judge which device is most efficient and indicates the lines along which further tests should be made.

The execution of these elaborate tests required a force of 25 men, which was made up as follows:

Dynamometer car operators	3
Observers and helpers	11
Computors	2
Mechanics	2
Assistant trainmaster with train crew	6
Inspector in charge	1

Inasmuch as it was found advisable to extend the experiments over a period of one and a half months or more, a conception may be had of the large cost involved in making an exhaustive investigation of this character.

Exhibit "B" is presented to show the accuracy of the readings. The depth of the water in the 19-in. pan on a perfectly quiet day, when the water was not agitated at all, was found to be, by actual measurements, ½ in. greater at station No. 2 than at station No. 1; hence station No. 2-No. 1 equals 0.50 in. as shown on the exhibit. Measurements taken during test No. 1406 showed that the depth at station No. 2 was ⅝ in. more than at station No. 1, which is ⅛ in. more than it would have been if the water had been perfectly quiet. The broken lines on the exhibit show to what extent the differences in depth of water from one station to the next, during several tests, varied from the actual differences, which existed when the water was perfectly quiet. Had the water been perfectly level and the measurements exact during these tests, the differences would have been uniform between any two stations. It will be seen that the variations from the average difference in depth is generally not more than ⅛ in., though running as high as ¼ in. occasionally. This may be accounted for in two ways: first, either the measurements are in error, due to the observer, or to the fact that the wind was generally blowing 10 to 30 miles per hour, causing considerable wave action in the trough, or, second, the variations may have actually existed owing to the winds causing a series of long swells. The effect of scooping, though apparently over, may have still left some surging.

The fact that a minus variation between two stations is generally followed by a plus variation at adjoining stations for any one test, tends to confirm the latter assumption. If the former is correct, the error in average depth for any test should not exceed one-tenth of an inch. This would correspond to 150 gallons in the 19-in. trough, and 225 gallons in the 29-in. trough. It is hardly likely that the results are in error this amount, as the plots of scoop performances would not have been as consistent as they are. It is seen, however, how very accurate the readings must be in order not to introduce large errors in the results.

A very ingenious and satisfactory scheme was used to obtain the immersion of the dipper during a test. Between each observing station a straight piece of telegraph wire about 3 ft. long was inclined in direction of traffic from bottom of trough (where it was hooked into an inlet hole) to the top, where it was held in position by a string stretched tautly across the trough to nails in a tie. This wire was coated with white lead. When the dipper strikes it, a well-defined line is scraped on its upper side, the string, of course, breaking. It was only necessary to straighten the wire slightly, place it in correct position on a template board when the exact distance dipper was above bottom of trough can be measured. Knowing this, and the relation of bottom of trough at wire gage to the bottom at observation station, where depth of water is measured, the immersion of dipper is accurately determined.

In Exhibit "C" is given a list of devices of which measurement tests were made, and diagrammatically is shown the gallons scooped and wasted per 1,000 ft. per inch immersion of the dipper for speeds of 20, 30, 40, 50, 60 and 70 miles per hour for each device.

In general the best results were obtained at speeds between 40 and 50 miles per hour. With reference to the unit of measurement adopted, namely, "gallons per 1,000 ft. scooped per inch of immersion of dipper," a series of immersion tests were run at 38 miles per hour, with the standard scoop over the 19-in. trough, and showed that between the limits obtainable (½ in. to 4½ in.) the amounts scooped were nearly enough in proportion to the amount of dip, to make this a very convenient unit of comparison. When the dip exceeded 3 in., none of the results varied more than 10 per cent. from the average ratio of scooping to dip. Exhibit "N" shows graphically the results of the immersion tests. Note Exhibit "N" attached.

The tests indicated that up to 2¾ in. dip, the quantity scooped increased more rapidly than the dip. When the dip exceeded 2¾ in. the amount scooped increased more slowly than the dip. The amount wasted was fairly constant for all immersions, with a minimum around 3-in. dip. The relation between the amount scooped and wasted and the dip varies for various types of scoops and troughs and is also affected by the speed.

In preparing Exhibit "C," results for each series of tests were plotted on a diagram similar to Exhibit "D," and an average curve drawn through the plotted points. Values on this curve for various

speeds were then read and plotted to make Exhibit "C." It will be seen by referring to Exhibits "F," "G" and "H," in which are shown sketches of the various devices tried, that the tests had to do largely with finding a suitable hood or deflector that would direct back to the trough water disturbed by, and not entering, the scoop. Most of the arrangements tried kept a large part of the spill between the rails and cut down the amount of it as Exhibit "C" shows.

It also appears that a hood with open front, such as Scheme No. 1, Exhibit "F," in some way cuts down the efficiency of the scoop, either by forcing a certain amount of air into the scoop or otherwise. Comparing the results in which this hood was used with those for the Wissenger device, Exhibit "G," which has a closed front, the advantage appears to be with the latter. From inspection in action, which, of course, can take note only of the amount and nature of the spill, the Wissenger device did not show up particularly favorable. The indications were that the bottom edge of the hood should not be straight or flat, but should be curved inward, both to deflect water into the trough, and at the same time allow most of the water thrown from the trough to rise up within the hood and fall back. In this latter respect, the Wissenger device fails, and deflects a good deal of such water out on the track.

Elmer's device, Exhibits "E" and "F," embodies the curved edge principle, and probably did as well as any of the hoods tried, the principal objection to it being its complication.

There are two pronounced sources of loss in the Pennsylvania Railroad scoop. One is due to a knuckle joint between the dipper and fixed portion of scoop. The joint works open and allows a considerable sheet of water to be thrown out. Another loss is due to the spout-like column of water that rises in back of the dipper and appears to shoot to the rear. A good deal of this column falls again to the trough, causing splash, some sprays outside and some is deflected by striking axles and brake beams.

One theory is that this column is occasioned by a vacuum forming in rear of scoop. An attempt was made to measure the amount of this vacuum by a water gage. It is not certain, however, that the few inches of vacuum obtained was not the effect of water flowing past the apparatus.

The column was less noticeable on the wide trough, until the walls were put into it, reducing the width of scooping channel, the previous effect being a general spray in all directions. It may be that the friction of the dipper against the sheets of water left in the bottom and along the sides of the trough would tend to curl these and so might form the column.

When a test was made with a piece of galvanized iron on the bottom of the dipper as shown in the lower part of Exhibit "H," the column was more pronounced and rose higher than with a plain dipper, apparently on account of angle "A" being greater. This, it is thought, lends some

weight to the friction theory. If it be possible to shape the back of the dipper, say like the stern of a boat, so that the particles of water leave it horizontally and directly backward, perhaps this loss can be overcome. Attempts to break down this column by a cross slit in the dipper, and by bifurcating it, as shown in lower part of Exhibit "H," were not successful and increased the amount of splash.

In seeking to control the column by a hood, designs like Scheme No. 3, Exhibit "F," and No. 11, Exhibit "G," that shoot the water down abruptly into the trough, causing splash, or that crowd it out at the sides, should be avoided. Designs like Elmer's and Schemes Nos. 12 and 16 with reverse curves are more efficient.

However, the most effective, and at the same time the simplest, device found for controlling this column is a flat plate in rear of the scoop, held as close to the trough as safe clearance will permit. The good effects of this plate, whether tried alone or in connection with the various shaped hoods, is always apparent in the results. It not only directs the column back into the trough, but quiets the water as well. There is some loss due to water from the trough striking the underside and deflecting out on the track, but this is not large. It is likely that, by means of angles properly placed, the loss, with the flat plate, may be still further reduced.

To overcome the loss due to opening the joint in the scoop, a leather lining was used. This, however, was not properly made, being straight instead of curved, as is the scoop. The result was that it choked the opening and so did not have the good effect that it ought.

While considerable latitude must be allowed individual opinion in interpreting experiments involving so many factors affecting the results, the following deductions appear warranted:

(1) In a well-designed scoop, the water delivered to tender may be taken as approximately proportional to the immersion of the dipper.

(2) The amount of water splashed increases,

(a) with the roughness and abrupt change in shape of exterior surface of the dipper. This almost axiom has been needlessly disregarded in practice;

(b) with the speed. The speed also determines the amount of water spilled due to choking at contracted sections of the scoop, the amount increasing as the speed decreases;

(c) with amount of water left in trough. Therefore, the closer the dipper fits the scooping channel, the less will be the splash.

(3) In hoods covering the dipper, intended to deflect back to the trough water spilled;

(a) The front should be closed to avoid cutting down the efficiency of the scoop;

(b) If the sides and top are drawn in towards the rear, they should follow easy reverse curves, and discharge the water directly and horizontally to the rear;

(c) The bottom edges of the sides should be curved inward, catching water from and deflecting water back into the trough;

(d) The closer the top of hood is brought to the trough, the greater the efficiency, because the lower the spilled water is kept the slower and less abruptly it may be returned to the trough, with less consequent secondary splash. Therefore, a flat plate covering the trough as closely as safe clearance will permit approaches the most efficient type of hood.

Exhibit "D" presents the results of some of the Pennsylvania Railroad, the Lake Shore & Michigan Southern and the New York Central & Hudson River Railroad tests reduced to a common basis. Exhibit "O" presents the results of extended tests made later by the Pennsylvania Railroad. The curves differ very slightly from those on Exhibit "D." It is seen that while the Lake Shore & Michigan Southern compares favorably with the Pennsylvania Railroad, the amount of water wasted by the New York Central & Hudson River Railroad and Michigan Central Railroad, particularly the latter, is very large. In examining Exhibits "I" and "J," showing the main features of these four scoops, for a possible explanation of these results, it is noticed that while the immersed portion of the Pennsylvania Railroad and Lake Shore & Michigan Southern dippers is smooth, that of the New York Central & Hudson River Railroad has a shoulder where the sheetiron fits over the casting, and that of the Michigan Central Railroad is covered with a 1¼-in. half-round band, making a very irregular surface for the water in the trough to flow past.

It is further noticed that the sectional areas of these latter two scoops at the top, where the velocity of the water is slowest, are from 20 per cent. to 50 per cent. less than the other two. As an example of how this restricted area affects the amount of water wasted, take the New York Central & Hudson River Railroad scoop, having an area of 0.54 sq. ft. at this point. Neglecting friction, the theoretical velocity necessary to cause water to flow to the height of this section is about 18 miles per hour. Hence, if the locomotive is scooping at 36 miles per hour, the velocity of the water at the highest section will be one-half that of the water entering the dipper, and consequently an area of 0.27 sq. ft. at the dipper will supply the same volume that can flow, freely, past the upper section. This requires an immersion of dipper of 3⅛ in. Any water scooped at a greater depth than this must be wasted except that in being thrown out, the wasted water reacts on the water in the scoop, giving it a greater velocity, and allowing a somewhat deeper immersion of the dipper than the speed of the locomotive alone could do.

If the locomotive were scooping at 54 miles per hour, the required area at the dipper would be two-thirds that of the upper section to furnish the same volume, and the dip required would be 4¼ in. It is clear that to avoid choking, the area of the upper section should be twice that of the area of the prism cut from the trough by the dipper at standard depth of immersion, when the speed is 36 miles per hour. At 27 miles per hour it should be three times and at 24 miles per hour four times this

prism area. A speed of 21 miles per hour would require seven times the prism area.

There can be hardly any question but that the poor showings of the New York Central & Hudson River Railroad and Michigan Central Railroad scoops are due to these two features of their design. It should be stated that the amounts of water scooped by the various roads are about the same, the difference being in the immersions and amounts wasted. Evidently it would be much to the advantage of the New York Central Lines to adopt the Lake Shore & Michigan Southern type of scoop as the standard, but before going to this expense it is very desirable to see in what ways the Lake Shore & Michigan Southern scoop can itself be improved. Comparing it to the Pennsylvania Railroad scoop, it is noticed that it enters the water more abruptly and that the water is required to take a much shorter turn at the top. It is not a question to be answered offhand as to what angle the scoop should best enter the water, but it is quite apparent that the deflection plate in the top of the Pennsylvania Railroad tender offers much less resistance to the water than the sharp elbow on the Lake Shore & Michigan Southern scoop. The Michigan Central Railroad scoop is undoubtedly better designed in this respect. There is also some question as to whether the water should not be thrown forward in the tender rather than to the rear. The forward throw might be more effective in filling the tender by more readily displacing the air, which is thought to be bound in the forward part of the tender when the water is discharged to the rear.

A plan accompanies this report entitled "Plan showing various applications of Locomotive Water Scoops now in use." This exhibits the details of construction of scoops used on several American railroads, including the four shown on Exhibits "I" and "J." Exhibit "L" presents the scooping arrangement employed by the Midland Railway of England. A brief description of its operation appears under the head of "Depth." It appears to be well designed, and its efficiency is said to be very high.

Exhibit "M" presents the scooping arrangement used on the engines of the Great Northern Railway of England. Especial attention is drawn to the patented device, designed to counteract the downward pull on the scoop caused by the inrush of water from the track tank when the engine is taking water at high speed. It may be of interest to those roads which employ hand-operated scoops, but is unnecessary when the scoops are operated by air. Its great drawback is that the lip, which projects into the pipe to divert part of the water into the cylinder, must necessarily reduce the efficiency of the scoop.

Under the head of "Width," mention was made of tests run by the New York Central & Hudson River Railroad in 1910. These were conducted at Herkimer and two type K-2 locomotives were employed for the purpose. The amount of water in the track tank was determined before and after scooping, also the amount of water delivered into the engine tank, the distance scooped, the speed and the depth of immersion of

the scoop dipper in each case. The elaborate appliances employed by the Pennsylvania Railroad were not available at Herkimer, but the measurements were taken with great care.

Some of the results are illustrated by curves in comparison with the Pennsylvania Railroad results in Exhibits "C" and "D." These results are of special interest, in that some warrantable deductions therefrom confirm the conclusions regarding the New York Central & Hudson River Railroad scoop, outlined above in connection with the description of the Pennsylvania Railroad tests.

At all customary running speeds, that is, from 30 to 60 miles per hour, about 60 per cent. of the water removed from the track tank was delivered into the engine tank and 40 per cent. spilled over the sides of the pan and wasted. This fact alone indicates that it should be possible to improve the design of the New York Central & Hudson River Railroad scoop and thereby increase its efficiency.

From the immersion of the scoop, its width and the distance scooped, a calculation can be made of the amount of water actually cut by the scoop dipper. It was found that this amount averaged about 85 per cent. of the amount removed from the pan. This is interpreted to mean that about 15 per cent. of the water actually removed came from points in the tank outside the limits of the scoop dipper, and this 15 per cent. must necessarily have been wasted.

Therefore, since 40 per cent. of the water removed was wasted, 15/40 or 37½ per cent. of the wasted water came from outside the limits of the scoop and the other 25/40 or 62½ per cent. of the wasted water must have been taken up by the scoop dipper and thrown back out again. These figures are necessarily only approximate, but they are sufficiently accurate to indicate in what directions we may expect to find what causes the water to be wasted.

The above statement may be looked at in another way. If 85 per cent. of the water removed from the track tank enters the scoop and 60 per cent. is delivered into the locomotive tank, 25/85 or 29 per cent., or nearly one-third, represents the proportion of the water entering the scoop that is thrown out again. This is strong evidence that the scoop under test did not offer an unobstructed passage for the free delivery of the water cut by the scoop dipper. It should be reasonable to assume that by enlarging the upper part of the delivery pipe above the scoop, the waste due to this cause could be materially reduced as has been previously suggested.

It was stated above that 15 per cent. of the water removed never enters the scoop at all. This waste, undoubtedly, could be lessened somewhat by removing the shoulder where the dipper is attached to the scoop proper so that only a smooth surface will be presented to the water. Any improvement in this direction would reduce the amount of water required to be pumped and to be heated and reduce the cost of maintaining the roadbed.

Any change in the design of the scoop that would permit a larger

proportion of the water entering the scoop to be delivered into the tender would be equivalent to increasing the length of the trough in the same proportion, and as the waste would be lessened, the cost of operation and maintenance would be reduced.

The cost of heating track tanks in winter is a large item of expense. For example, on the New York Central & Hudson River Railroad, where the direct application of steam is employed, a 100 horsepower of boiler capacity is required in severe weather for heating two tanks 27 in. wide and 1,400 ft. long. A 27-in. trough of the New York Central & Hudson River Railroad type could be safely reduced 4 in. This would reduce the amount of water surface exposed to the atmosphere about 15 per cent. and would reduce the amount of steam required for heating in about the same proportion.

Hence, these troughs could be reduced 4 in. in width and increased 210 ft. in length, which is the same ratio, without affecting the cost of operation. Such action would, no doubt, destroy the value of the reserve supply in the wide tank, but this loss would be more than offset by the gain in supply due to the increased length and at the same time the scooping efficiency would be improved.

CONCLUSION.

Track tanks should, preferably, be located on tangents and where good drainage can be provided, also where good water is abundant, and at sufficient distances from stations and all other facilities which would prevent trains from attaining a speed of at least 25 miles per hour. Modern power equipment is capable of hauling an enormous tonnage, and the tendency is to still further increase the size and capacity of locomotives. Therefore, in order to avoid the necessity of unreasonably increasing the water tank capacity of engines, the distance between trough stations should not exceed 40 miles, unless other controlling conditions require it.

The design of the power plant required cannot be outlined in detail for standardization, because this depends much on local conditions. Boiler capacity of 100 horsepower will, in general, heat about 7,000 sq. ft. of water surface in troughs, by means of direct heating system, sufficiently to prevent the water from freezing during the most severe weather encountered on the New York Central Lines. Accordingly, four standard troughs, as recommended, would require about 220 horsepower of boiler capacity for heating purposes.

Duplicate pumps should be installed to insure continuous service. The capacity of each pump should, in general, be about double the average hourly consumption of the plant. A boiler capacity of from 40 to 80 horsepower will be required for pumping. Pumping may be dispensed with when a good supply of water can be obtained by gravity. Sometimes the water is obtained from deep wells and can be most advantageously elevated into the storage tanks by means of the air lift,

compressors in this case replacing the pumps. Usually water from deep wells is comparatively warm, so that, if scooping is frequent, very little heat is required to prevent freezing.

Some scoops are very inefficient, and it would seem reasonable to expect that the best could be improved. The design of the scoop used on the Lake Shore & Michigan Southern Railway appears to be the best of any used on the New York Central Lines. As pointed out above, any improvement in the efficiency of the scoop not only reduces the cost of operating the plant and the cost of maintaining the roadbed, but is equivalent to increasing the capacity of the track tanks. There also appears to be a greater opportunity to economize in this way than in any other in connection with the operation of troughs. It is, therefore, recommended that the design of the scoops be given further consideration.

RECOMMENDATIONS FOR STANDARD PRACTICE.

(a) A trough 2,000 ft. long, 7 in. deep, and having a width that will provide an inside clearance of 19 in. It should consist of two standard 7-in., 9.75-lb. channels, with flanges turned in to form the sides and a flat plate ¼ in. thick and 23¼ in. wide, riveted to one flange of each channel, to form the bottom. This type of section is recommended because it is cheaper to construct, install and maintain than the customary type. The ties should be dapped 2¼ in. to receive the trough. This can be done safely and is sufficient to maintain the top edges of the trough below the top of the usual 100-lb. rail, when the trough has become somewhat uneven, as it always does after it has been in service for a time.

(b) The end sections should be constructed with the bottom plate inclined at an angle so that the length of incline will be 10 ft. The plate should be ½ in. thick and secured to the side channels by angles riveted to each. The beginning of the incline where the scoop would first hit should be backed by an iron wedge and the balance backed by hardwood.

(c) The direct heating system is advised on account of it being less expensive to install and maintain, and being more efficient. The headway of trains is being considerably reduced in connection with the inauguration of automatic signals requiring five inlets to each trough in order that it may be refilled quickly enough. Five inlets in connection with the circulatory system would render the cost of installation excessive.

(d) The drainage system, shown on plan entitled "Standard Track Tank; Drainage for Direct Heating System," is recommended, because it is effective in disposing of the spilled water and can be easily installed and maintained.

REPORT OF COMMITTEE XIV—ON YARDS AND TERMINALS.

C. H. SPENCER, *Chairman;*
W. G. ARN,
HADLEY BALDWIN,
W. C. BARRETT,
G. H. BURGESS,
A. E. CLIFT,
H. T. DOUGLAS, JR.,
A. C. EVERHAM,
GEO. P. JOHNSON,
D. B. JOHNSTON,
E. B. TEMPLE, *Vice-Chairman;*
H. A. LANE,
L. J. MCINTYRE,
B. H. MANN,
A. MONTZHEIMER,
W. L. SEDDON,
E. E. R. TRATMAN,
W. L. WEBB,
J. G. WISHART,
Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Yards and Terminals submits herewith its Thirteenth Annual Report.

The Board of Direction has assigned the following subjects to your Committee:

(1) Report on typical situation plans of passenger stations, of both through and stub types, with critical analysis of working capacity, and include a review of the different methods of estimating their capacity.

(2) Report on developments in the handling of freight by mechanical means.

(3) Report on developments in the design and operation of hump yards.

Various meetings of Sub-Committees have been held during the year, and a meeting of the entire Committee was held in Pittsburgh, September 27 and 28.

(1) TYPICAL SITUATION PLANS OF PASSENGER STATIONS.

(1) In the development of the subject the Committee presents, in Appendix A, situation plans and description of the business handled at passenger stations:

Baltimore.....Baltimore & Ohio Railroad
Baltimore.....Pennsylvania Railroad
Boston.....South Station
Philadelphia.....Baltimore & Ohio Railroad
St. Louis.....Union Station
Washington.....Union Station

(2) In arriving at a description of the business handled at each station, the following outline has been used:

(1) Handling of mail;
(2) Handling of express;
(3) Handling of baggage—
  (a) Individual;
  (b) Theatrical.

(4) Passengers—
- (a) Through;
- (b) Local;
- (c) Suburban.

Each item should be considered apart from any other, particularly as to that which fixes the maximum capacity in a certain unit of time, say, one hour. This would be followed by consideration as to whether this speed or maximum capacity could be sustained for a longer period. Finally the four headings would be considered as applied to each layout.

(3) The Committee offers three methods of graphical critical analysis of working capacity of throat and station tracks at a station.

The first method has been used by the Belgian State Railway and is shown in article by Messrs. Weissenbruch and Verdeyen in Bulletin of International Railway Congress, Vol. XXII, No. 9, September, 1908.

The second method has been used by the Pennsylvania Railroad in studies of the Broad Street (Philadelphia) Station.

The third method has been designed for the Committee work this year.

A method devised for the Dirschau Passenger Station and described in Bulletin of International Railway Congress, Vol. XXIII, No. 2, February, 1909, is, after consideration, not recommended.

The essentials to be shown on diagram for analysis of working capacity of a passenger station are:

(1) Occupation of station tracks—
- (a) Capacity of each track;
- (b) Time of occupation;
- (c) Make-up of trains;
- (d) Movements, if any, on internal crossovers in station.
- (e) Number of trains and route arriving and departing and direction of movement.

(2) Movements on throat tracks—
- (a) Arbitrary time over route;
- (b) Whether scheduled trains, drafts, road engines or switch engines;
- (c) Route used before entering and after leaving, and direction of movements;
- (d) Interference from cross movements.

Each of the three methods submitted has stood the test of application to extremely heavy traffic conditions.

DIAGRAM OF TRAIN MOVEMENTS AT CAMDEN STATION, BALTIMORE, MD., USING BELGIAN DIAGRAM.

The diagram showing train movements at Camden Station, Baltimore & Ohio Railroad, is an application of the diagram which is in use on the Belgian State Railways, and was worked out by officers of that system. It was explained by L. Weissenbruch and J. Verdeyen in the Bulletin of the International Railway Congress issued in September, 1908.

In applying this diagram to Camden Station there were certain minor features added to those given in the above Bulletin, especially the table showing the capacity of tracks and the symbols used to designate the number and kind of cars occupying the platform tracks. This was for the purpose of showing whether or not two trains could occupy the platform track at the same time.

For a full explanation of the Belgian diagram reference should be had to the Bulletin mentioned.

In the diagram of Camden Station two hours were selected in which the number of movements was at a maximum. Many of these movements were switching movements, as the diagram shows, and during the particular time chosen the station platforms were not utilized to their full capacity for inbound and outbound main line trains. This period was selected and the diagram prepared to show especially the possibility of representing internal switching movements as well as the movements of trains and light road and switching engines.

The method of indicating the routes of switching movements is slightly different from that of the Belgian method, but seems to show clearly the continuity of all switching work which took place at the above station and the tracks used.

The diagram as applied to Camden Station shows its use for both a terminal station and a through station, since tracks 1 to 7 inclusive are stub tracks in the train shed, while tracks 8 and 9 are on a lower level entering the Belt Line Tunnel on the main line between Philadelphia and Washington, constituting a through station.

The fundamental idea of the Belgian diagram is to select a certain number of platform tracks, access to which is secured over one track, or a short stretch of a track, which can be called the "running line" of the group selected, such as tracks 2, 3 and 4 on the diagram, which are reached by the westbound track marked "1," also tracks 5, 6 and 7, which are connected with the eastbound track, which is called the running track of those three station tracks. Tracks 8 and 9 show in reality a through station, and, therefore, have two running lines, which are tracks 1 and 2 on the diagram for the territory west of the station, and tracks "a" and "b," representing the running lines for the east end of the station. These are shown in dotted and broken lines to avoid confusion, and to distinguish them from the running lines of the terminal portion of the station.

In order to represent routes and to immediately detect movements which would foul each other, numbers are selected as shown on the diagram to indicate the different routes.

The value of the diagram depends entirely upon the selection of the running lines and the numbers representing routes. The route numbers and the station platform numbers can be made different in design, and running lines should be shown in dotted and broken lines or in lines of different colors. There may be several selections of running lines and routes, but after one or two trials the arrangement that gives the greatest station capacity will be easily determined.

The upper half of the diagram shows the track layout; the lower half represents the movements, and the legend in the title explains the characters used.

Vertically the diagram is divided into minutes, and covers the period from 5:30 p. m. to 7:30 p. m. The horizontal lines represent platform tracks and running lines. The numbering of routes and internal fouling points shows at a glance along any vertical line whether there is a confliction of movement. Reading from the top down, the numbers representing the routes must increase in size, or it means that the movements conflict, because they take place on the same route or fouling point at the same minute. The number of the train is written below the line representing its movement. Arrows pointing to the left are movements out of the station or towards the west. Arrows pointing to the right are movements into the station or towards the east. The time which is consumed by any movement on the running line is represented by the length of the movement line drawn on the running line. These movement lines are all shown very much heavier than the lines representing station tracks or running lines. The close movements on the north running line shown on the diagram as taking place at about 6:47 could not be allowed if the movement were main line train movements. As they are all switching and light engine movements it is permissible to run them as closely as shown during those few minutes.

The switches in this layout are all controlled from the tower, but the interlocking arrangements do not require an entire route to be set up and maintained until the movement has cleared the whole block.

This diagram covers the five essentials which have been submitted by the Committee as necessary for a graphical analysis of working capacity of a passenger station in regard to the occupation of station tracks. By the table at the right-hand side of the diagram the capacity of each track may be ascertained. It shows the composition of the train or cut of cars occupying the track and the length of time that the different trains or cuts occupy that track, and whether there are cars taken off or added to those on the track. It shows internal movement, also the number and route of arriving and departing trains with their direction. As applied to the movement through throat tracks or fouling points, the numbers are placed at these fouling points and show the route, the arrows the direction of movements, and the symbols as noted in the legend the class of movements, such as trains, light road or switching engines, or switching engines with a cut of cars. The time that is taken by a movement on any track is shown by the length of the heavy movement line as drawn on the line representing that track on which the movement is taking place.

This brief description, with the reference to the Bulletin of the International Railway Congress for September, 1908, will give a clear idea of the intention of the diagram, and a detail study will suggest the many possible ways in which it may be used. In all diagrams the lines should be large enough and sufficiently spread out to be seen at a glance.

All diagrams at first seem quite complicated, but after giving a little time to thoughtful study and becoming thoroughly familiar with the

meaning of each symbol, it is very easy to read them, and they can then be used correctly and quickly.

The make-up of the diagram would depend considerably upon the purpose for which it might be employed. A Superintendent or Station Master, in making a study for rearranging station movements to secure greater capacity, would not need as large a diagram, nor possibly the same kind of a diagram, as would be needed by a towerman, or a Train Dispatcher, who must handle an emergency movement.

It is possible that we might have a station used practically to its maximum capacity, and a certain train might come in late, or on some days there might be unexpected heavy excursion movements, and a diagram to fulfill this purpose should show at a glance at what time, on what track and by what route the different trains could be received. A towerman who has been working for any length of time in a certain tower would probably not have occasion to refer very frequently to this diagram, but a new man would use it constantly, until he became thoroughly steeped in the knowledge of the facilities which he has to handle.

The Belgian diagram gives a very complete picture at a glance, and concentrates on one chart all fouling points and tracks so that the whole situation is shown on the same sheet. It is complete in its representation; it can be spread out if the number of train movements are large, and after a knowledge is had of the fundamental principles it is very simple and can be read without hesitation.

It is most important, however, that to secure full value of the diagram, we make a careful selection of the running lines and the numbers representing routes and fouling points.

DIAGRAMMATICAL METHOD OF SHOWING ACTUAL OCCUPATION AND WORKING CAPACITY OF STATION AND THROAT TRACKS, BROAD STREET STATION, PHILADELPHIA, PENNSYLVANIA RAILROAD.

For a number of years past, it has been apparent that the track layout of station and approaches at Broad Street Station, Philadelphia, is seriously congested by the train movements incident to handling the service of that terminal.

This condition is most in evidence during the rush hours, or peak load periods of the morning and evening, at which time any interference with the normal movement of traffic, such as occurs during severe weather, results in disorganization of the service and consequent delays to trains, from which recovery is slow.

The need for additional relief led to the appointment about two years ago of a Board of Engineers to study the whole situation, and prepare plans and submit a report for additional facilities. The Board in their report gave careful consideration to the adoption of electric traction for the suburban service terminating at Broad Street Station, with the result that a Transportation Committee, composed of operating men, was ap-

pointed to consider with the Board of Engineers the possibilities of an electrified suburban service, particularly as to the relief that would be afforded in the operation of the train service at Broad Street Station.

In considering the problem, the Committee's first thought was to devise some means of showing graphically the conditions actually existing at the station and on the track approaches, during the peak load periods, or hours of maximum train service; the train movements handled during such hours requiring the maximum demand on the facilities provided. It was necessary that these diagrammatic studies, to be of practical service, should be of such a nature that the results obtained through any change in operating methods could be clearly indicated on the original charts. The charts fully met expectations, and were indispensable in studying the overcrowded condition of the terminal and the resulting changes that would ensue from electrification.

An analysis of the station and throat track layout develops the fact that there are six route or throat tracks at 18th street connecting the eight elevated approach tracks to the sixteen station tracks, over which all passenger train movements are made. A movement over any given route will, of course, block such route for other movements from the moment the route through the interlocking is set up until the movement in question clears the fouling point. It is also evident that when such a movement involves the use of switches which are necessary to the movement of train units over one or more of the five remaining routes, the routes so fouled are blocked until the movement in question clears.

It was apparent from these facts that with the proper data at hand, graphical charts could be prepared that would show all movements actually made over the throat tracks, including blockade of routes, and would indicate the extent to which these facilities were used. This method was, therefore, adopted and the necessary data obtained in the following manner:

Four men were stationed at "A" cabin from 8:00 to 10:00 a. m. and from 4:00 to 6:00 p. m. on a certain day, two of whom were assigned to recording the inbound and two to the outbound movements. All train movements to and from Broad Street Station are made under the direction of a Train Director stationed at "A" cabin, from which the interlocking at the throat of the station is controlled. Each movement to be made was called by the Train Director to the signalmen, the movement as called indicating the route, elevated track and station track involved, and whether inbound or outbound. Proper record of the movement was made by the first of the two men recording movements in that particular direction. This man also recorded in each case the character of train unit, the number of cars, engine numbers, etc., as well as the actual time to the nearest quarter minute of the setting up and clearing of the route in question, as these facts were noted by the second man, who was thoroughly familiar with the interlocking.

In preparing the throat track charts, the six routes were plotted as adjacent parallel spaces of convenient width and length, on which time was indicated by perpendicular lines. Each individual movement made

DIAGRAM A.

DIAGRAM OF TRAIN MOVEMENTS—CAMDEN STATION, BALTIMORE & OHIO RAILROAD.

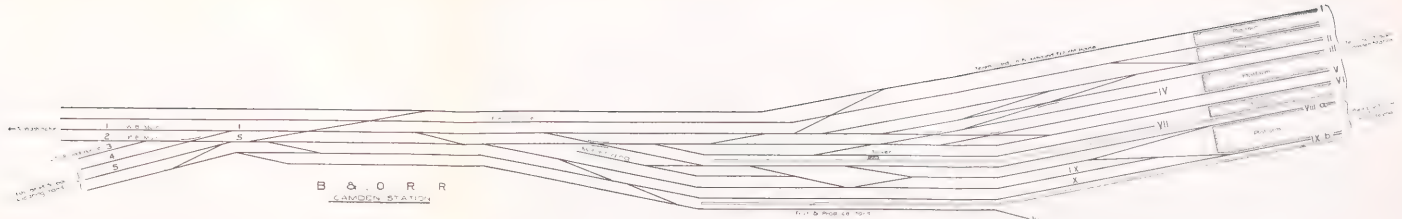
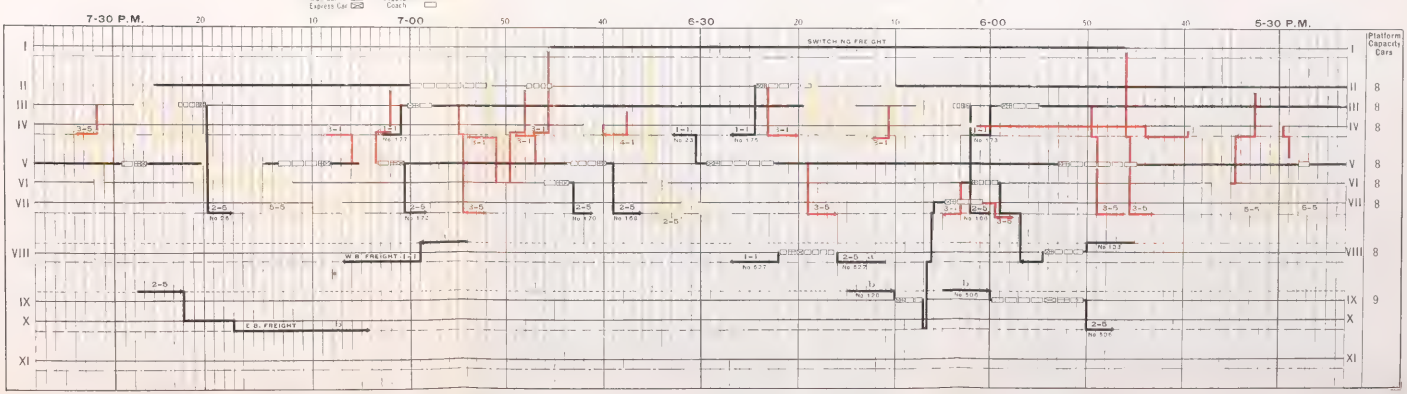


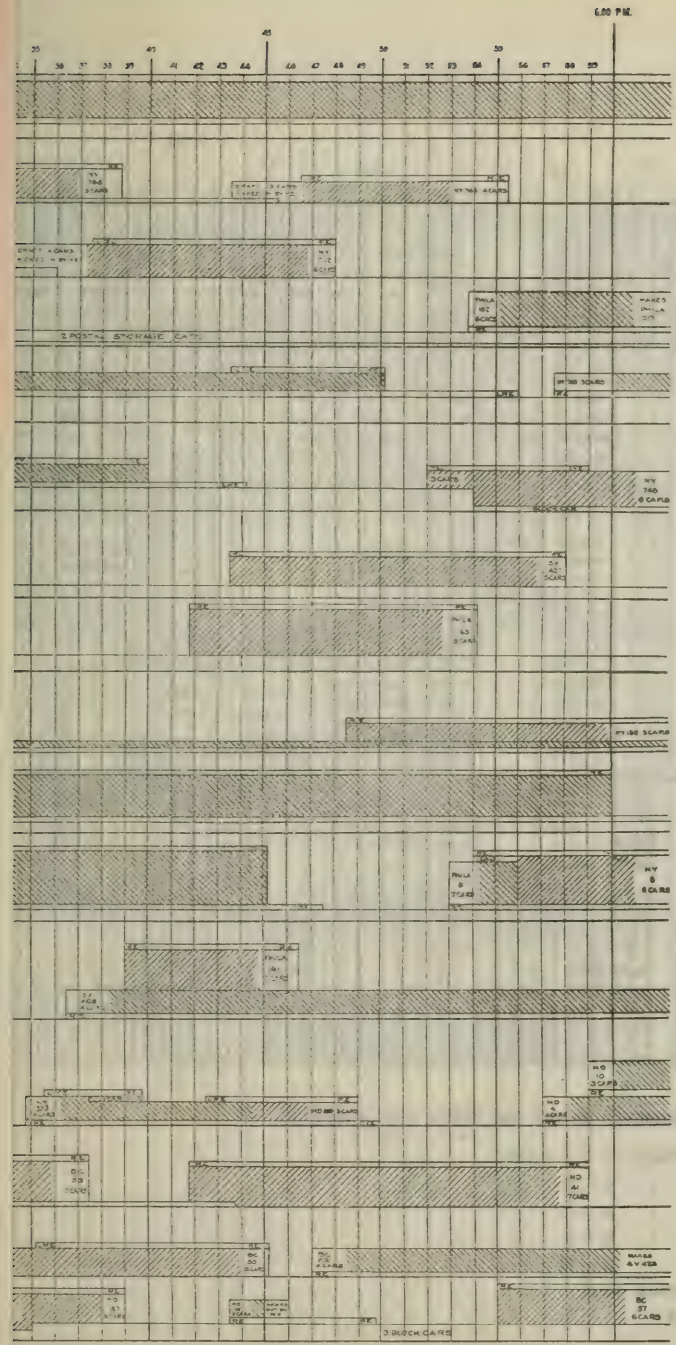
DIAGRAM A.

DIAGRAM OF TRAIN MOVEMENTS.

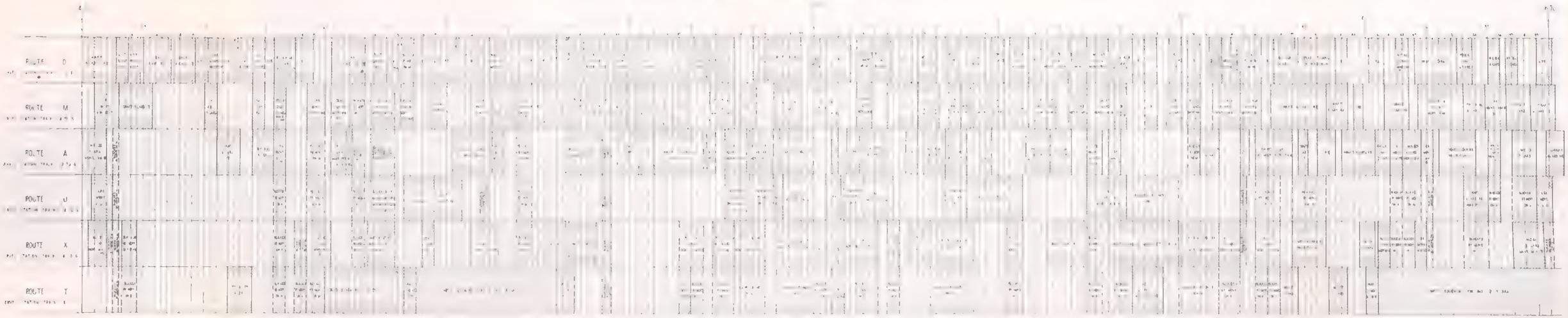
September—1912

Trains
Light Road Engine
" Switching Engine
" with cut of cars
Running Lines for Terminal Tracks East of Tunnel
West
Mail Car
Express Car
Baggage Car
Coach





ROOM (65 CARS) FOULING ONE ROUTE
1 TO 13 INCL INDICATES CAR STANDING ROOM (65 CARS) FOULING NO ROUTES
TO WHICH TRACKS ARE OCCUPIED
D


ROUTE D
ROUTE M
ROUTE A
ROUTE U
ROUTE X
ROUTE T

BROAD STREET STATION,
PHILADELPHIA, P. R. R.

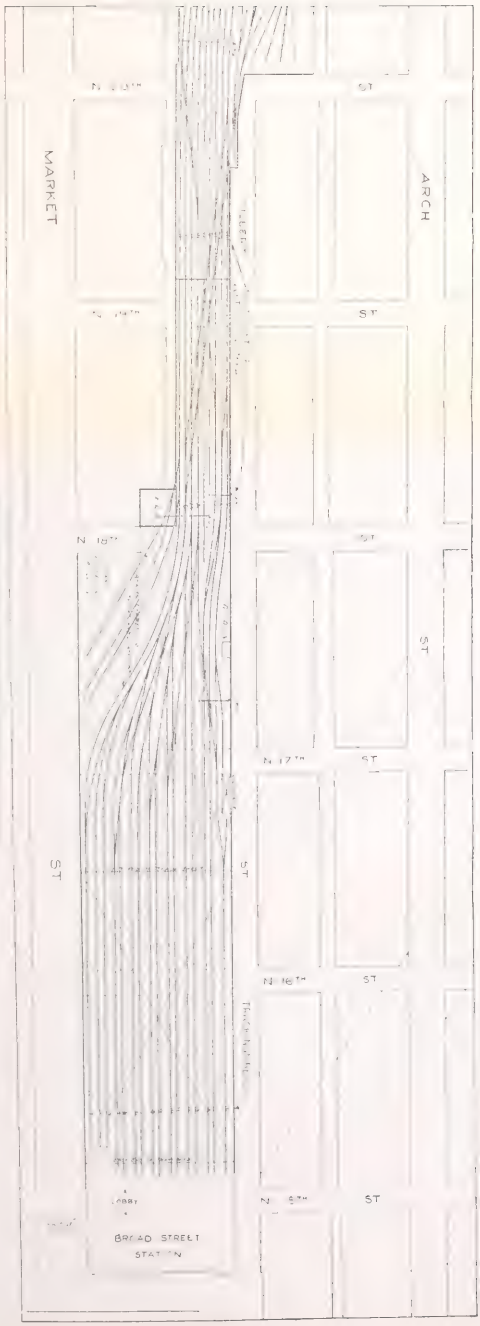
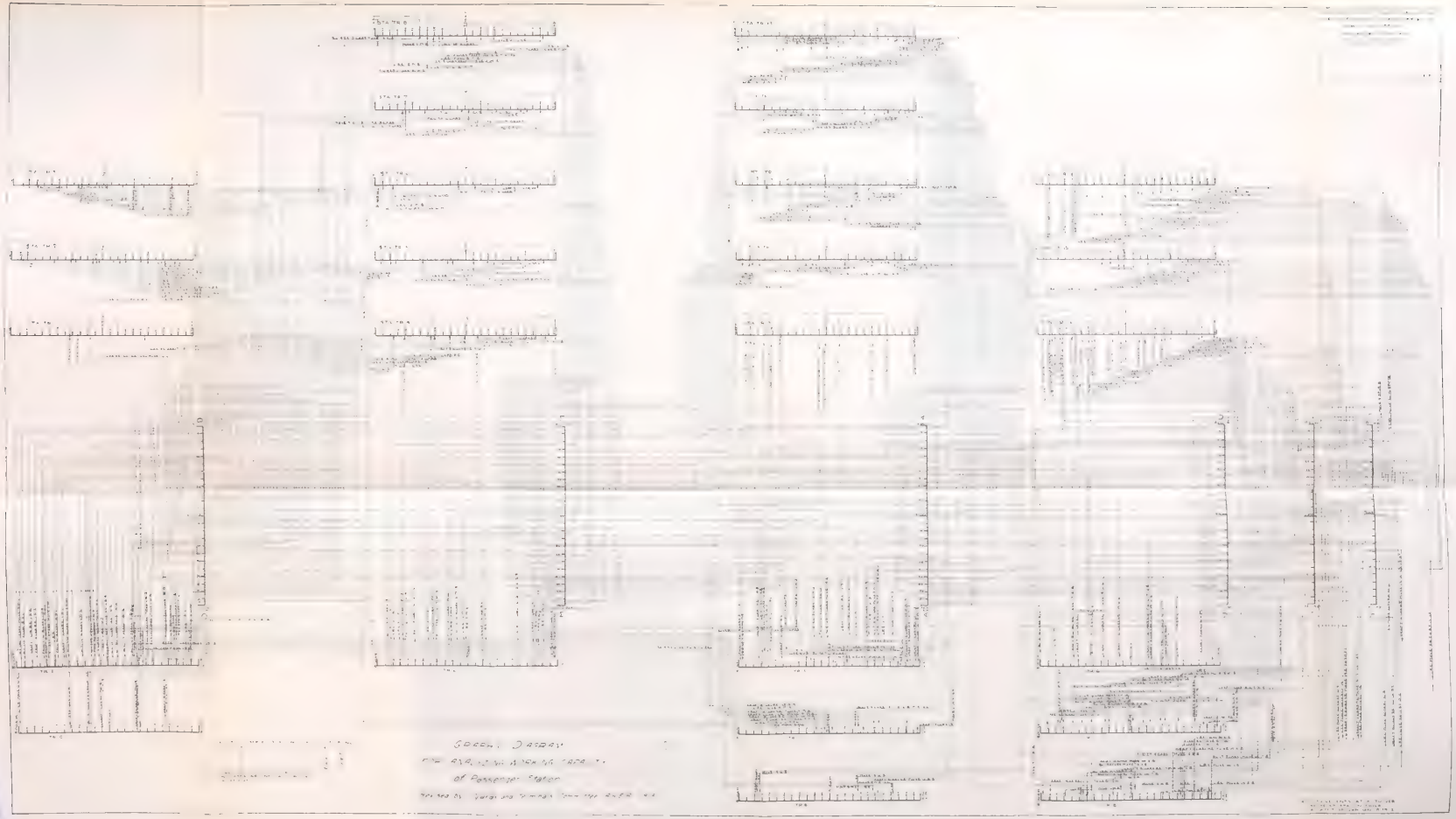

MARKET
ARCH
ST
N. 18TH
N. 17TH
N. 16TH
N. 15TH
BROAD STREET
STATION

DIAGRAM D.

CRITICAL ANALYSIS OF WORKING CAPACITY OF PASSENGER TERMINAL.



over the different routes was plotted as a solid line rectangle, cross-hatched with solid lines to show direction of movement and covering the time included between the actual setting up of the route and its clearance by the movement in question. The blocking of routes other than the one actually in use by any given movement was shown by rectangles, cross-hatched with dotted lines. The character of each train unit handled was indicated on the charts, and, where blockades of other routes resulted, the actual movement made was shown.

Similar diagrams were also prepared from the above-mentioned data, showing, respectively, the occupancy of station tracks, and the movements made on the eight elevated passenger tracks between the interlockings at "A" and "B" cabins, but these latter diagrams are not here submitted.

The station track diagrams show, by means of rectangles, the equipment properly designated, occupying the different station tracks during the busy hours, and the time of arrival or departure of each train unit. The width of track spaces and train diagrams are drawn to scale, and the relative amount of track room occupied by each train unit is, therefore, indicated.

Examination of these diagrams or charts indicates very clearly the congestion now existing, and shows conclusively that the tightest place is at the throat of the station, and that the six routes in their capacity for handling movements are not evenly balanced. This condition is due to the character of the track layout, whereby routes D, M and A on the south side of the terminal, collectively reaching all station tracks, must be used exclusively by movements to and from tracks Nos. 1 to 13, inclusive, while routes U, X and Y reach and serve only tracks Nos. 14 to 16, inclusive, the result being that routes D, M and A are taxed beyond their capacity.

These different charts are well adapted to the study of the results to be obtained from electrification; the elimination of shifting movements that would follow the use of multiple-unit electric traction for certain groups of trains being readily indicated on the original diagrams.

The re-plotting of trains can be done without introducing unknown factors, as it is only necessary to adhere to the figures obtained in actual practice, as given in the tower records and plotted on the original diagrams. If new trains are to be introduced, a glance at the station chart will show what platforms are available at any particular time, and, by referring to the throat track chart, one can easily ascertain whether the movement can be made at the desired time without interference with existing conditions.

The daily number of scheduled trains when the tower record was taken in January, 1912, was 543; the number of scheduled trains in the busy two-hour period from 4:00 to 6:00 p. m. was 78, and 286 movements were made in both directions past "A" tower in the same period.

In addition to suburban and long distance passenger trains, a large amount of baggage, mail and express must be cared for. The handling of theatrical scenery and some full carload lots of periodicals is undertaken at West Philadelphia.

GRAPHICAL DIAGRAM DEVISED BY COMMITTEE FOR USE IN ANALYZING WORKING CAPACITY OF PASSENGER STATIONS.

PURPOSE.

The purpose of the graphical diagram showing working capacity of passenger station is twofold:

(1) To make clear the necessity for changes in design in the way of revision of or additions to the track layout.

(2) To lay out a working time card.

REQUISITES AS TO STATION TRACKS.

It is desirable to be able at a glance for each station track to see relatively for any instant:

(a) The capacity and the space yet available.

(b) The make-up and amount of equipment occupying.

(c) The scheduled time of arrival and departure of such equipment.

(d) The switching movements required on any connecting internal crossover.

(e) The route arriving and departing, and the direction of the movement.

REQUISITES AS TO THROAT TRACKS.

The diagram should show clearly:

(1) What throat tracks directly serve the various station tracks without interference with other routes, also, similar information as between the throat tracks, and the different main or running tracks outside of the station.

(2) The arbitrary time consumed by a movement over a throat track from the time the route is set up until it is cleared.

(3) Whether the movement is a scheduled train, draft road engine or a switch engine.

(4) The route used before a movement enters a throat track and after it leaves.

(5) The direction of the movement.

(6) Any interference from cross movements.

The method of graphical analysis designed for the Committee contemplates satisfying each of these requisites. It has been applied on the attached diagram to the Broad Street (Philadelphia) Station, for which data was available covering the approximately one hundred and fifty (150) movements that are regularly made in the two-hour interval, 8:00 a. m. to 10:00 a. m. Such heavily congested traffic was selected so as to thoroughly test the method.

On the diagram heavy lines plotted as coordinates represent, respectively, the abscissa or horizontal line the station track, the ordinate or vertical line the throat track, and a second abscissa the main running track. A line is provided for each unit in these three classes of tracks

A scale representing hours and minutes is plotted on each of these lines. For clearness, no less than one-twentieth of an inch should be allowed for each minute.

INFORMATION AS TO STATION TRACKS.

The capacity of each station track may be shown by a number placed against the station track line to show its length in cars. Each station track line is also marked to show the number of track which it represents. The amount of space available on any track at any instant is the difference between the number of cars shown in any movement or movements occupying the track, and the total capacity of the track. Each occupying movement is shown by a relatively thin line paralleling and alongside of the station track line, and marked as to the character and make-up, both in cars and engines. The time of arrival and departure of any movement is shown by the minute on the scale at which the movement line, now extending vertically, crosses the track line. The heavy horizontal scale lines representing the station tracks jointly served by any certain throat tracks are assembled in a parallel group. The switching movements required on any internal crossover connecting with station track may be shown by drawing thin movement lines from the proper point, as to scale, on the occupation line on one track, through the proper point on the scale of the track to which the crossover connects, paralleling the latter during the time of occupation, and returning vertically again to the original occupation line on the first track. The route arriving and departing for any movement is shown in order by the figures and letters plotted on each movement line near the point of origin or ending on the station tracks, and denotes the respective station tracks, throat tracks and running tracks occupied. The direction of the movement is shown by an arrow. For example:

> On track 14, at the time of the beginning of the diagram, 8:00 a. m., there was a draft of four cars, which had been placed on the track some time previous. At 8:02 a. m., a train of six cars also entered this track, occupying it until 8:10, at which time its draft of six cars with road engine was backed out of the station. The light road engine for the first draft entered this track at 8:12. Another train entered the same track at 8:17 with six cars, occupying it until 8:20, and backed out with the road engine. Yet another train entered the same track with six cars at 8:22, occupying it until 8:31, and backed out with the road engine. At 8:34, the original draft of four cars with the road engine left the station as train M. D. No. 1.

EXAMPLE NO. 2.

> On station track 14, at 9:34 a. m., M. D. train 38 with five cars entered. A second train, New York 291, with four cars, entered this track at 9:36 and backed out with its road engine at 9:42. The light yard engine backed in on the draft of the M. D. train 38 on this track at 9:43, and pulled out with the draft at 9:47. The light road engine, which brought in M. D. trian 38, backed out at 9:48.

INFORMATION AS TO THROAT TRACKS.

The relative position of the vertical lines representing the throat tracks, and the horizontal lines, representing respectively the station tracks and the running tracks, show the grouping as to direct connection one with the other. The arbitrary time consumed by a movement over a throat track from the time the route is set up until it is cleared is measured by the minimum space allowed between the crossing movement lines on the vertical scale line representing the throat tracks, and may also be shown by a number representing the minutes and placed at one end of the throat track line. The scales used should be no less than one-twentieth of an inch to the minute for clearance sake. The vertical lines representing the throat tracks are respectively marked with the letters used to designate each throat track. The conventional movement lines, in addition to being designated at the points of origin and ending by figures and letters denoting as to whether they are trains, drafts, road engines or switch engines, and also as to the route used before a movement enters a throat track and after it leaves, may also be distinguished as to classification of movement, by the use of different colors, just as is customary in the use of strings or lines denoting on an ordinary railroad district time-card chart somewhat similar classification. The direction of a movement is given by the arrows at the points of origin and ending, and the interference of a movement on any throat track is shown by the fact that the movement line passes across each and every throat track line that may be blocked by the movement. For example:

> Continuing reference to the movements mentioned in illustrating use of the diagram on station tracks, and referring to the train M. D. 38 with five cars, which arrived on track 14 at 9:34 a. m.; also following the conventional movement line, it is apparent that this movement used throat track "U" at 9:31 a. m., on its way through the station approach from running track No. 7, which it left at 9:30½. No other throat track was blocked and the diagram so shows, as the movement line intersects no other throat track line than that representing "U."

EXAMPLE NO. 2.

> New York train 837 with five cars left running track No. 2 at 8:37, via throat track "M," and entered station track 11 at 8:38.

Whereas on the station tracks the interval of time occupied is measured by the distance between the points of crossing of the movement entrance and exit lines over the station track scale lines; on the other hand, on the throat track the movement line crosses the scale at a point in the middle of the arbitrary time during which the route is blocked by the movement. For example:

> Should this arbitrary time on any route or throat track be two minutes, in reading the diagram a spacing of two minutes between any two movement lines at the crossing points of the route track scale would indicate that the route was blocked by one movement at the instant it was cleared by that which pre-

ceded. Should the spacing between two adjacent movement lines on this scale have been four minutes, an interval of free time between the two movements of two minutes would be indicated.

Should it be desired to handle a new train with four cars at the terminal, the time of arrival having been given by the management as 9:35 a. m., and the division delivery such as to make the use of running track No. 7 practicable, it will be noted on the diagram that there is clear space at that time on running track No. 7 and on throat track "X" and available room on station track 15, and instructions that the movement will be so handled may at once be given. Traffic conditions also show that this is about the only place in the station at that time where this movement could be handled without probable delay.

Should it be desired at any terminal to use this method in laying out a working time card, chart boards of a size sufficiently large to suit the purpose will be provided, on which will be permanently plotted the scale line conventions for the station tracks, throat tracks and running tracks. The movements would be indicated temporarily by lines of different colors and would be shown upon the chart by means of strings fastened by pins, as is done on the ordinary railroad district time chart. Tags properly marked and attached to the pins at the originating and terminating point of the movement would give the detail information required, so that after the movements are plotted to meet requirements of the proposed new time card, the information could be checked and called off in the customary way for making up the printed working list, showing arrival and departure of trains and tracks used for each.

Should certain movements during any interval of time appear to create an undesirable congestion of traffic, a rearrangement of the strings on the chart may be studied and put into effect, and the possible interference brought about by any such change anticipated and avoided.

Should one or more station tracks appear to be handling more than their share of the traffic, similar attention to the chart or diagram can be given, and if no other solution develops, the necessary slight changes in track connections may be made.

Where congested traffic demands, the working charts or diagrams need only be limited in size by the space on the wall available and within reach, and as a rule, where the traffic is as congested as in the Broad Street Station, extra sets of charts may be required to satisfactorily cover the day's work. One possible good feature of this method is that it may be handled personally by transportation men, making use of the colored strings, and may be revised and rearranged by them quickly to suit any change in traffic conditions.

The make-up of the trains may, if desired, be shown on the diagram also by conventions, representing arbitrarily each style of equipment, placed in order on a line at right angles with each station track scale line and against the time of arrival or departure, indicating the mail, express, baggage, coaches, dining cars, sleeping cars and parlor cars.

IN GENERAL.

The Committee recommends that for the design of a large passenger terminal there should be considered the situation plans submitted to the Association in 1911, and shown in inserts opposite page 240, Vol. XII, Part 1, of Proceedings, eliminating the notation 1-7 as applied to angle of ladder. These layouts would be expanded or multiplied in such a way as to best meet the requirements of the real estate owned at any particular location.

The Committee also desires to emphasize the possibility of the substitution of inclines or ramps in place of stairways in busy stations. In all such stations where track level is above or below street level, stairway connections have the objection of interrupting and checking the flow of travel at busy hours. This is especially the case where much suburban traffic is handled.

It is of interest to note, therefore, that in the new Grand Central terminal at New York inclines have been adopted at several points, presumably because they were considered safer and more expeditious than stairways. The grade of these inclines seems to be eight per cent. Experiments have been made to determine the grade best adapted for convenience. In many places there is not space available for such inclines, but in designing new stations this feature might well be studied.

In the design of a large passenger terminal the Committee presents for adoption the following conclusions:

(1) A holding yard should be directly connected with platform tracks to provide for a quick emptying and refilling of the latter.

(2) At passenger terminals, where large quantities of baggage and express must be handled, and it does not appear expedient to provide intermediate platforms to be used exclusively for this service, it is recommended that, where conditions permit, baggage and express be received, delivered and handled below or above the train floor (as grade conditions demand) and raised and lowered by elevators, conveniently located, to avoid interference with the movement of passengers.

NOTE—Conclusion of 1911 amended by providing for handling baggage and express above as well as below train floor and inserting "as grade conditions demand."

(3) To provide for proper coupling of cars a maximum curvature for storage and loading tracks of six degrees is recommended.

(4) For safe, efficient and economical operation on station throat tracks the curvature through switches should not exceed that of a No. 8 slip on tangent.

The Committee presents as a progress report, without recommendation as to relative merits, the three methods of graphical analysis of working capacity of a passenger station.

Appendix A.

BUSINESS HANDLED AND SITUATION PLANS AT VARIOUS PASSENGER STATIONS.

Description of business handled at and situation plans of the following stations:

Baltimore—Baltimore & Ohio Railroad Station.
Baltimore—Pennsylvania Railroad Station.
Boston—South Station.
Philadelphia—Baltimore & Ohio Railroad Station.
St. Louis—Union Station.
Washington—Union Station.

NOTE—In arriving at a description of business handled at each station, the following outline has been used:

(1) Mail handled,
(2) Express handled,
(3) Baggage handled.
  (a) Individual,
  (b) Theatrical,
(4) Passengers handled,
  (a) Through,
  (b) Local,
  (c) Suburban.

Analyzing the layout for each subject:

(A) What individual feature fixes the capacity of the station?
(B) What is the capacity of this feature?
(C) How many full cars can be spotted to load or unload for each character of work?
(D) How long does it require for loading?

The information is as follows:

BALTIMORE—CAMDEN STATION—BALTIMORE & OHIO RAILROAD.

(1) MAIL.

(A) The amount of mail that can be handled by trucks.
(B) Depends on amount of mail that can be transferred while trains wait.
(C) No carloads handled.
(D) About ten minutes as maximum on through trains.
  On trains originating at this point, mail cars are placed from thirty minutes to two and one-half hours before leaving time of trains. Through trains must wait until all mail is loaded.

(2) EXPRESS.

(A) Length of track along express platform and storage space.
  Carload lots are handled at express yard.
  Small packages loaded by trucks while trains wait.
(B) Six cars on house track.
(C) Six cars.
(D) Cars placed from thirty minutes to five hours before leaving time. Carload lots taken exclusively by express train No. 1, which classifies here and then allows fifteen minutes for loading. Parcel express packages loaded on through trains in three to thirteen minutes.

(3) BAGGAGE (INDIVIDUAL).

(A) Size of baggage room and number of men employed. All baggage trucked to and from trains.
(B) Baggage room covers 3360 sq. ft.
Parcel racks consist of 48 compartments, each 3' 9"x 1' 6" by 3' 4" deep.
Largest number of pieces of baggage handled in one day, 1250.
(C) Baggage cars are handled in regular trains, 39 inbound, 40 outbound.
(D) Depends on number of pieces of baggage.
Maximum about ten minutes.

BAGGAGE (THEATRICAL).

(A) (B) (C) Four cars of theatrical baggage handled.
(D) Cars placed at noon, baggage handled at night.

(5) PASSENGERS.

(A) Two through tracks on belt line, four in station shed and one on short line (electric).
Coaches for trains originating and terminating at this station are cleaned and prepared for service in Coach Yard near Bailey's roundhouse, and coaches are then set on tracks in station or on stub track next to cut.
(B) Belt line 12 cars westbound, 10 eastbound, station shed 32 cars.
(C) Belt line 22 cars, station shed 32 cars.
(D) Through trains two to five minutes.

BALTIMORE—MT. ROYAL STATION—BALTIMORE & OHIO RAILROAD.

(1) MAIL.

(A) Amount of mail that can be handled by trucks.
(B) Depends on amount of mail that can be transferred while trains wait.
(C) No carload lots handled.
(D) Very little mail handled, and no delay to trains on this account allowed.

(2) EXPRESS.

(A) No regular express office, except as receiving station for U. S. Express.
All express goes to Camden Station for distribution. Only express business at Mt. Royal is known as "parcel-stamp express."
(C) No carload lots handled.
(D) Loading from trucks must be during scheduled stay of trains.

(3) BAGGAGE (INDIVIDUAL).

(A) Size of baggage room and number of men employed. All baggage trucked to and from trains.
(B) Baggage room 45 ft. x 50 ft., with office 17 ft. x 15 ft. for Station Master, and 7x9 ft. for Baggage Master.
Parcel rack has 14 compartments, averaging approximately 3 ft. x 1 ft. 6 in. x 1 ft. 6 in.
Number of pieces of baggage per day, 100.
Number of "Parcel stamp express" per day, 50.
Number of U. S. Express packages per day, 60.
(C) Baggage cars handled in regular trains, 21 inbound and 24 outbound.

(D) Depends on number of pieces of baggage.
Maximum about 10 minutes.
Theatrical cars are spotted early in the morning and unloaded during the day; outbound are generally brought up with New York sleeper and handled at night.

(4) PASSENGERS.

(A) Four running tracks, two of which are also used for freight.
(B) Twenty-eight cars.
(C) Twenty-eight cars.
(D) Usually not over two or three minutes.

BALTIMORE—UNION STATION—PENNSYLVANIA RAILROAD.

The new Union Station, Baltimore, which was placed in service Sept. 15, 1911, is located north of Jones Falls and between Charles and St. Paul Streets, on practically the same site as the old station which was demolished March 18, 1910, to make room for the new building. The station tracks are of the through type, and form a part of the main route of Pennsylvania Railroad trains between New York, Philadelphia, Baltimore, Washington and the South over the Philadelphia, Baltimore & Washington Railroad. A junction is made south of the station with the Northern Central Railway tracks, extending to Harrisburg and points north, and the Union Station is owned by that company, which is part of the Pennsylvania System.

The approach to the station for Philadelphia, Baltimore & Washington Railroad trains in both directions is by means of double-track tunnels, and that for Northern Central Railway trains is along the valley of Jones Falls (a small stream bisecting Baltimore from north to south). Passenger trains of the Western Maryland Railroad also reach Union Station via the southern tunnel.

The baggage and express trucks cross the tracks at grade near each end of the station.

There are seven tracks adjacent to four platforms for the handling of the passenger business.

The through and local freight movement is cared for on separate tracks located north and south of the station driveway and passenger tracks, so that there is a clear movement for passenger trains between the portals of the tunnels, where junctions are made with the freight tracks.

The daily train service is as follows:

Through trains via P. B. & W. R. R. and N. C. Ry....	68
Originating and terminating express of long distance local trains via P. B. & W. R. R. and Northern Central Railway	56
Suburban trains via P. B. & W. R. R. and N. C. Ry....	57
Western Maryland Railroad trains.....	18
Total number of trains daily.....	199

The scheduled stop of through trains is from 2 to 14 minutes, with an average of five minutes.

Trains originating at Union Station occupy the station tracks on an average of ten minutes, and those terminating five minutes.

There are 33 trains scheduled between the hours of 6:00 and 8:00 p. m.

The station and tracks are easily operated with the present schedule, and the probable difficulty in future operation with an increased schedule will be the delay in handling baggage to and from the trains standing on the platform tracks, and in disposing of the passenger and freight movements at the junctions north and south of the station near the portals of the tunnels.

UNION STATION AND TRACKS, PENNSYLVANIA RAILROAD, BALTIMORE, MD.

Theatrical scenery is not handled at this station, and no U. S. mail and Adams express cars are loaded or unloaded, except in trains, on account of the limited space available for independent tracks for such purpose. This business is all taken care of at Calvert Station, located one mile downtown along Jones Falls.

BOSTON SOUTH STATION.

(IN GENERAL.)

(A) There is no individual feature fixing the capacity of the station. It depends almost entirely on the respective roads entering the station and their ability to get their trains to and from the station.

(B) The capacity of this feature is practically one hundred trains per hour.

(C) There can be 344 65-ft. passenger cars against the station platforms (352 cars in under the train shed).

(D) There can be 116 cars in express yard, 52 against the platforms, 93 on other tracks, which may be loaded or unloaded from teams. There are 50 full express cars received and 50 forwarded daily at present, in addition to express handled in combination baggage and express cars on local trains.

MAIL.

There are 25 mail cars received and 25 forwarded daily at present time. Cars are set in the express yard against the platform by request of the Government, time varying from thirty minutes to two hours before leaving time. The average capacity for handling mails is 250 tons per day.

BAGGAGE (INDIVIDUAL).

Number of baggage cars arriving, 300; forwarded, 300, not including combination express and baggage cars.

The particular feature covering baggage rooms is perhaps the position of the rooms, which are on either side of station. The outward baggage room being 530 ft. long by 26 ft. wide, with 16 doors off the street for receiving, if needed. Only one-half of the doors are continually used, and meets the demand satisfactorily. The inward baggage room is 470 ft. long by 26 ft. wide, with from 10 to 15 doors that can be put in service for deliveries if business demands. Only a part, however, are in continual use. The baggage room has a capacity for handling 2,500,000 pieces of baggage annually. The present average daily handling through the rooms is 5,100 pieces, with a maximum record of 13,000. The checking counters are at the head of each room, directly open and in an inviting and attractive position to the public, handy to enter and return from the midway or the street. There are a large number of checkers on hand at all times, with assistants passing checks along, preparing baggage for immediate attention for forwarding to trains, the checks being conveniently arranged within the reach of the checkman.

BAGGAGE (THEATRICAL).

Theatrical cars are loaded on special tracks and set at specified times to remain at the convenience of the shippers.

PHILADELPHIA—BALTIMORE & OHIO RAILROAD STATION.

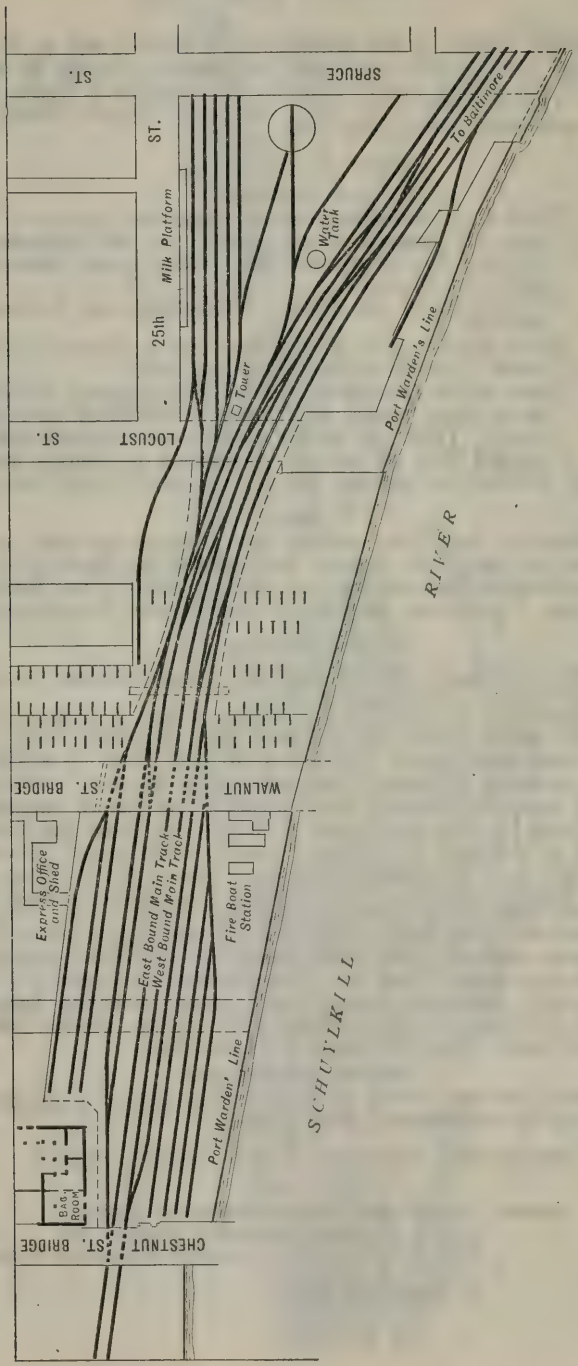
(1) MAIL.

(A) Amount of mail that can be handled by trucks.

Loaded on trucks and taken to mail car.

Mail from train No. 122, which terminates at this point, is trucked to wagon.

No siding for mail.



BALTIMORE & OHIO RAILROAD STATION, PHILADELPHIA.

(B) Depends on amount of mail that can be transferred while trains wait.
(C) No carload lots handled.
(D) When more than two truckloads are handled, passing trains are liable to delay.

Mail car placed on train No. 517, originating at this point, two hours before leaving time, and mail is put on about one hour before starting.

(2) EXPRESS.

(A) Length of track at express platform.

All small packages received in baggage room and conveyed by trucks to trains.

(B) Four cars, each 70 ft. long.
(C) Four cars.
(D) Express cars for carload lots are placed at express platform six to eight hours before leaving time of train.

Small packages from station must be loaded from trucks during scheduled stay of train, otherwise they are detained at this point.

Outbound business has precedence over inbound.

(3) BAGGAGE.

(A) Size of baggage room and number of men employed. All baggage trucked to and from trains.
(B) Baggage room 37'x46', parcel room 35'x22'. Parcel room has four cases for packages, made up as follows:

15 compartments, 3 ft. 9 in. x 1 ft. 5 in. by 1 ft. 5 in. deep.

4 compartments, 3 ft. 6 in. x 1 ft. 9 in. by 1 ft. 10 in. deep.

8 compartments, 5 ft. x 1 ft. 9 in. by 2 ft. 6 in. deep.

8 compartments, 6 ft. x 1 ft. 9 in. by 2 ft. deep.

Largest number of pieces of baggage handled in one day, 650.

(C) Baggage cars handled in regular trains; 34 each way.
(D) Depends on number of pieces of baggage. Sometimes loading takes longer than allowed by schedule for stay of train at station.

BAGGAGE (THEATRICAL).

(A) Two tracks for theatrical cars.
(C) Four cars.
(D) Theatrical cars are spotted about noon of day of leaving; some baggage loaded during the day, the balance after performance.

(4) PASSENGERS.

(A) Three running tracks for through trains from Locust Street to Chestnut Street. Two tracks for local trains, and sometimes one through track for locals arriving. Coach Yard in addition to running tracks; also siding between Coach Yard and eastbound track for storage of cars.
(B) and (C) Through trains 27 cars, local 10 cars, Coach Yard 22 cars, siding 4 cars, total 63 cars.
(D) Through train three to seven minutes.
Local trains five minutes.

ST. LOUIS—UNION STATION.

(1) MAIL.

(A) The number of special trains assigned for mail handled and the Government regulations as to advance setting of cars.
(B) Tracks are assigned to handle 61 full cars each way.
(C) The number which can be set varies with the space assigned and depends entirely upon the demand.
(D) Cars must be, by requirement of Post Office authorities, set from one to six hours in advance of leaving time and require, as a rule, thirty minutes for unloading.

(2) EXPRESS.

(A) The length of spur tracks at express platforms.
(B) and (C) Thirty-nine 70-ft. cars aside from local shipments in baggage cars which are handled at train platforms.
(D) Cars are set and remain at express platforms at convenience of express companies.

There are 35 full express cars received and 35 forwarded daily, at present, in addition to express shipments handled in combination baggage and express cars on station tracks.

(3) BAGGAGE (INDIVIDUAL).

(A) The space assigned for storage and the number of men employed.
(B) The present daily average is 5000 pieces; maximum handled in one day 14,800 pieces.

A space 2 ft. wide, 2 ft. high and 4 ft. long should be allowed for each trunk. The aisles between the piles of trunks should be 12 ft. wide. Each checker should be provided with three linear feet of counter space, the aisles between the counter and the checking racks being 5 ft. Each check rack for country wide baggage handling where no more than two or three checkers are employed should be allowed a space 2 ft. 4 in. wide, 6 ft. 8½ in. high and 10 ft. 9 in. long.

Where a large number of checkers are employed each check case should be of such size and in such units as to avoid confusion. Where there are several roads and several men employed checking baggage, all checks should not be confined to one large case, but each case should be approximately 24 in. wide, 18 in. deep and 7 ft. 6 in. high, two drawers being included at the bottom for storage. In such event each check case of dimensions as noted should cover the requirements of two roads or routes.

(C) Baggage cars are set with the trains; 144 baggage cars arrive daily and 144 depart, including combination cars.
(D) Thirty minutes is allowed for either loading or unloading cars.

BAGGAGE (THEATRICAL).

(A) (B) (C) Capacity of special team yard outside of station building, which capacity is now ample and will cover future growth.
(D) Cars are allowed to remain at convenience of shipper.

(4) PASSENGERS.

(A) There are five running tracks between bridge 14 and bridge 11, the entire length of entrance to station, as shown on attached cut. The time required for a movement from one end of

these tracks to the other and reversing into the station is approximately four (4) minutes. The capacity on this basis for movement, allowing necessary interference as between crossover movements and east and westbound movements, is 45 trains per hour. Trains from the east and north enter the limits of the station at bridge 14, move to bridge 11, and back into the station. Trains from west and south enter at bridge 11, move to bridge 14 and back into the station.

(B) (C) (D) Checking these figures by the capacity of the station tracks, this capacity with the 32 tracks being for 330 80-ft. coaches with a minimum of a 10-car train and engine for each track, allowing 31 tracks on which trains arrive and depart, and providing a 30-minute "set," as required, and necessary allowance for interference for each case of cross movement, gives 10 minutes for each movement in or out, on the basis of 45 trains per hour capacity.

Including the train shed, there is, in connection with this station, a storage capacity of 981 80-ft. coaches and 77 70-ft. coaches or express cars.

So long as 30 minutes is required, arbitrarily, for each train in the station, the capacity of the train shed and the capacity of the five running tracks across the head of the station practically balance.

The local trains are handled in the same way as the through trains, except that such trains which, as a rule, originate within 100 miles of St. Louis arrive in the middle of the day, when business is light and the capacity of the shed is not taxed.

In the suburban business a 15-minute headway is the capacity for two tracks in a shuttle service and has been so tested out in service.

WASHINGTON, D. C.—UNION STATION.

(1) MAIL.

(A) The number of special cars assigned for mail handled and the Government regulations as to advance setting of cars.

(B) Tracks are assigned to handle forty-four (44) inbound and forty-five (45) outbound, full, combined or storage cars.

(C) The number of cars which can be set varies with the space assigned and depends entirely upon the demand.

(D) Cars must be, by requirement of Post Office authorities, set from one hour to six hours in advance of leaving time to handle the advance distribution, and require, as a rule, thirty (30) minutes for unloading.

(2) BAGGAGE (INDIVIDUAL.)

(A) The space assigned for storage and checking baggage.

Sufficient facilities have been installed to care for all of the traffic in this station, allowing for a very considerable growth over present business.

(B) Daily average is approximately 5,600 pieces, maximum day during September, 1912, 6,400 pieces.

(C) Baggage cars are placed with trains, 107 arriving and 110 departing, including combination cars.

(D) From ten to thirty minutes is allowed for either loading or unloading a car.

(3) BAGGAGE (THEATRICAL).

(A) Space assigned for placing theatrical cars.
(B) and (C) Maximum capacity eighteen (18) cars.
(D) Cars are allowed to remain at convenience of shipper.

MILK.

A considerable quantity of milk is handled at milk platform. Track assigned for this purpose has a capacity of eight cars.

Five full cars unloaded and loaded daily. Milk is also trucked from regular baggage cars to milk platform. Sixteen thousand gallons of milk is handled daily.

(3) EXPRESS.

The Adams, Southern and United States companies handle express at Washington. Practically all of the Adams and Southern companies express is handled from cars at express platform, while a very large part of the United States express is handled on through cars, the Washington express being trucked to and from cars on station platforms.

(A) The length of spur tracks at express platforms.
(B) and (C) A total of 37 75-ft. cars can be placed on express tracks; 22 cars at platform.
(D) Cars are set and remain at convenience of express companies.

There are a total of approximately 219 cars of express handled in Washington per day, not including combination baggage and express cars. Of the above, 120 cars are handled at express platforms, 60 cars in and 60 cars out. The balance, 99 cars, are through cars, and are not handled at express platforms.

(4) PASSENGERS.

Washington is essentially a transfer station, where trains entering the station are broken up and cars made up into new trains or added to departing trains. This causes a large amount of switching through the interlocking at north end of station tracks and in throat of tunnel, and very greatly restricts operation.

There are nine throat tracks entering the station from the north.

Two roads enter the station over these tracks: Pennsylvania on the extreme east side, the Baltimore & Ohio, Washington Branch, immediately west of the Pennsylvania at "C" Interlocking, and the Baltimore & Ohio, Metropolitan Branch, on the extreme western side of throat.

Arbitrary running time between "C" Interlocking and Union Station is three minutes. Block signals are so arranged that trains may follow each other at intervals of approximately two minutes.

Coach Yard and Round Houses are located north of New York Avenue, and all equipment and engines are handled through throat tracks.

Switching for express yard is done on the easternmost throat track.

Trains entering Washington from the north are handled on station tracks 1 to 20, both inclusive, on an elevation of main floor of Union Station. Southern roads enter Union Station by means of twin single-track tunnels, approximately 4,800 ft. long. Trains are handled on station tracks 21 to 29, both inclusive, at an elevation of 21 ft. below main floor of the station.

The arbitrary time over south approach to tunnel and through tunnel is four minutes, tunnel being operated as absolute block.

All equipment going to the Coach Yard from low-level tracks must cross the movement of both Baltimore & Ohio, Washington Branch, and Pennsylvania trains.

The number of trains which can be handled at the Union Station depends entirely upon the character of the train, the amount of switching necessary at the station, and whether a through or terminating train.

UNION STATION AND APPROACHES,
WASHINGTON TERMINAL CO.,
WASHINGTON, D. C.

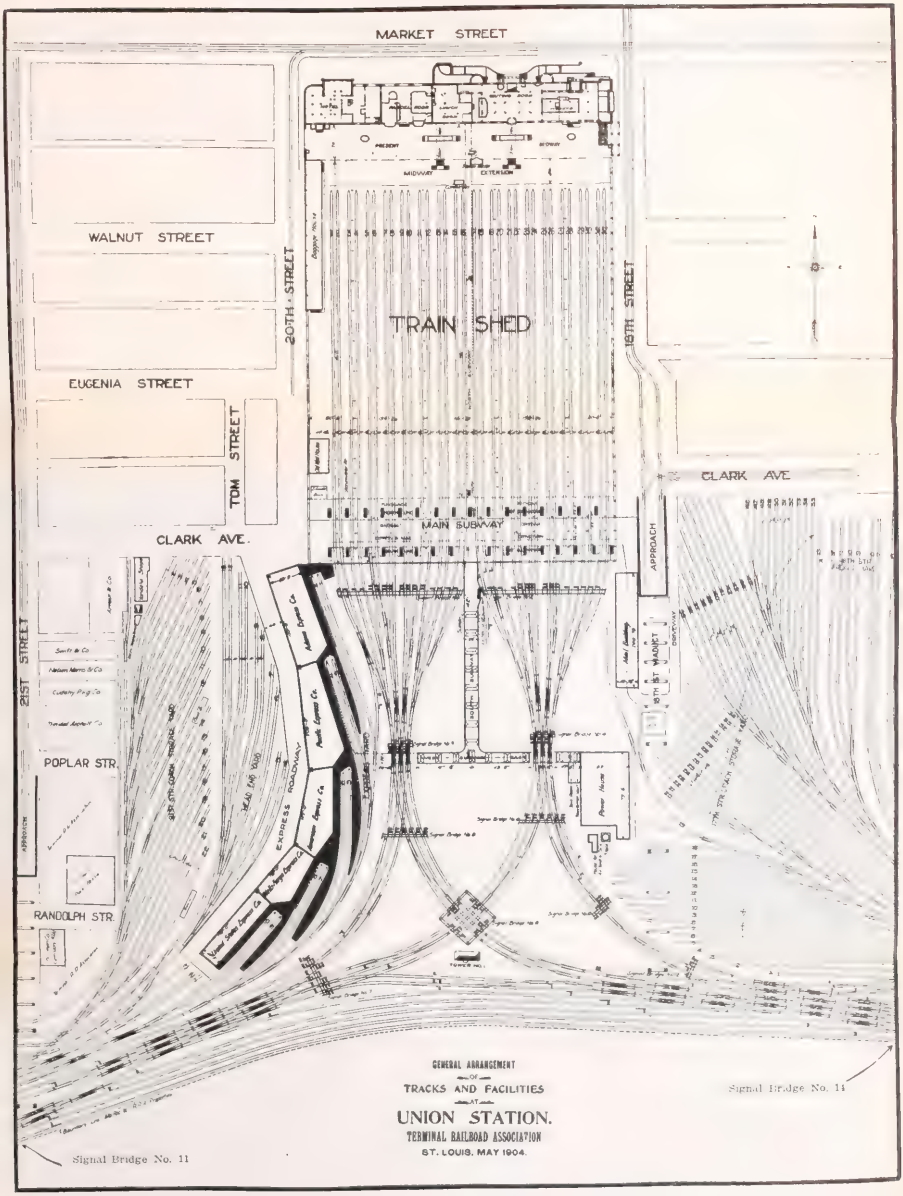
CAMDEN STATION, B. & O. R. R.,
BALTIMORE, MD.

TERMINAL STATION AT BOSTON, MASS.,

BOSTON TERMINAL CO.

GENERAL PLAN OF TERMINAL STATION AT BOSTON, BOSTON TERMINAL CO.

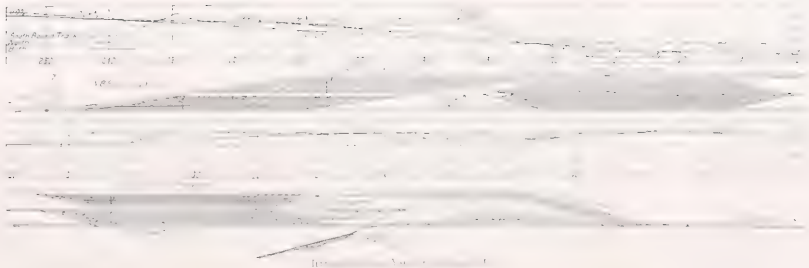
UNION STATION, TERMINAL RAILROAD ASSOCIATION, ST. LOUIS, MO.



GENERAL ARRANGEMENT
OF
TRACKS AND FACILITIES
AT
UNION STATION.
TERMINAL RAILROAD ASSOCIATION
ST. LOUIS, MAY 1904.

GODFREY (ILL.) YARD,
C., M. & ST. P. RY.

ILLINOIS CENTRAL YARD
AT CENTRALIA, ILL.



Present facilities are more than ample for present traffic.

While no opportunity has as yet been afforded to demonstrate what the Terminal would be able to accomplish, it is estimated that, allowing for crossover movements and station switching, 50 trains per hour could be handled, 25 in and 25 out. Maximum number of trains handled in one hour at the present time, 20—6 in and 14 out.

The capacity of high-level station tracks is 279 75-ft. cars and low-level station tracks, 107 75-ft. cars.

Very little suburban business is handled at this station.

DESIGN AND OPERATION OF HUMP YARDS.

Circular letters were sent out during the year to a number of large railways, and as far as the Committee was able to ascertain, the only large hump yards built during the last year were the Centralia, Ill., Yard of the Illinois Central R. R. and the Godfrey, Ill., yard of the Chicago, Milwaukee & St. Paul Railway. A small hump yard has been partially constructed by the Kentucky & Indiana Terminal Railway near Louisville, Ky., but as some changes are to be made in plant, it will not be possible to make any report on the yard at this time.

The Centralia yard will be put in operation about December 1, 1912, On this account it will be impossible to give any detailed results of the actual operation of the yard in this report. The mechanical plant at the Centralia yard will not be completed until the spring of 1913.

The yard, as constructed, has but one hump, and this will be used for classifying northbound freight only. Provision has been made, however, for the construction of a second hump for classifying southbound business, should it be required. The main tracks are separated and yard located in the center so there will be no traffic crossing over mail tracks. Southbound main is located twenty feet from yard tracks.

The classification yard consists of seventeen (17) tracks, the center tracks in the yard, when completed, being the highest, each track from the center of the yard outward being one-tenth of a foot lower to facilitate drainage. Yard tracks are 13-ft. centers.

The frogs are No. 8, and the arrangement of the switches at the hump end of the classification yard was the result of careful study to require the least amount of curvature possible.

The turnouts to the center tracks of the completed yard have been so arranged that a car switched to these tracks has less degrees of angle to turn than cars going to the outside tracks. This is necessary on account of the center tracks in the classification yard being about 1.7 ft. higher than the outside tracks. The grade through the turnouts is 1½ per cent. This is a little more than usual, but was thought necessary on account of trouble encountered in a number of hump yards, due to cars stalling on turnouts.

The grades on the hump are less than in yards constructed several years ago, and were adopted after making a careful study of other hump yards, it having been found in actual practice that in some cases grades were too steep, which caused damage to cars and necessitated more riders. Grades on this yard are as follows

.4 grade up to the hump.
25 ft. of 1½ per cent. rising grade to bunch cars for uncoupling.
25 ft. level grade at summit.
25 ft. of 4 per cent. falling grade.
100 ft. of .8 per cent. falling grade.
275 ft. of 1.2 per cent. falling grade.
700 ft. of 1½ per cent. falling grade through the turnouts.
700 ft. of 1 per cent. falling grade.
1100 ft. of .2 per cent. falling grade.
Remainder of yard .1 per cent. falling grade.

The present classification yard consists of 17 tracks, holding 80 cars each. The ultimate yard provides for 33 tracks in the classification yard.

Cut List			Cut List		Cut List		Cut List	
No. of Cut	No. of Track	Cars In Cu	No. of Track	Cars In Cut	No. of Track	Cars In Cut	No. of Track	Cars In Cut
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2								
3								
4								
5								
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7								
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A clear running track is provided on the east side of the yard for engine movements.

At present, no track scale is provided on the hump, but provision has been made for locating the scale there, and it may be constructed at some future time. At present, track scales are located at the extreme south end of the yard, and it is proposed to have road crews weigh any cars necessary before pulling into the yard. Plan and profile of the Centralia yard accompanies this report.

The construction of the C., M. & St. P. Ry. yard at Godfrey was commenced in 1910. The eastbound yard was completed in 1911. Work on the westbound yard was started early in 1912 and will be completed in December, 1912.

The main tracks were formerly located through the westbound departure yard and immediately south of the eastbound classification and receiving yard. They have since been changed to the position shown on the plans north of the westbound yard. Plan and profile of the Godfrey yard accompany this report.

Yard tracks are 13-ft. centers. The angle of the lead tracks are 7 deg. 57 min. in receiving yard and 8 deg. 18 min. in the classification yard. Frogs are all No. 10, excepting slip switches, which are 8 deg. angle.

From the vicinity of the westbound hump yard to the east end of the yard there is a drop of about 10 ft. in the general surface of the ground, which is favorable for eastbound movement, but adverse to westbound movement. This made it necessary to do a large amount of grading in the westbound yard, adding considerably to the cost of the yard. This expense was justified, in our opinion, as thereby a forward movement was secured for westbound cars.

When the yard was first designed plans were made for taking westbound cars to the west end of the yard and hump them to the east, thus making a back-up movement for these cars. This plan would have caused congestion in the yard and increased the operating expense, so it was abandoned.

As this yard has not been operated as a whole, it will be impossible to include in this report any information as to the actual results, but it is hoped the Committee will be able to make report on the operation of this yard at some future time. The repair tracks have not yet been located and, therefore, do not show on the plans.

The Committee feels that a careful study should be made of the operating conditions of all hump yards and results tabulated to see if improvements cannot be made in some of these yards to secure better efficiency.

CONCLUSIONS.

Recommendation No. 1.

Where tracks are set aside for holding empty cars, the grade leading to such empty tracks should be increased so that empty cars will move with the same velocity as loaded cars switched to adjoining tracks.

Recommendation No. 2.

The Committee has investigated the "Cut List" system of handling cars on the hump and recommends it as being safe and efficient. This system is briefly described as follows:

The yard clerk makes up a list of cars to be switched and tracks they are to be placed on in receiving yard, cut No. 1 being the first car to go over the hump.

Cut list form accompanies this report. It is perforated on three vertical lines, so the list may be divided up into four parts, each part being a duplicate of the other.

Where switches are thrown from a tower, one copy of the list is given to the towerman and one to the man cutting off cars on the hump. Where switches are thrown by hand, each switch tender has a copy of the cut list, as well as the man cutting off cars on the hump.

DEVELOPMENT IN THE HANDLING OF FREIGHT BY MECHANICAL MEANS.

During the past year the Committee has made considerable study of the mechanical handling of freight, especially as to the work carried on at the freight house of the Missouri, Kansas & Texas Railroad at St. Louis; the Baltimore & Ohio Railroad, Pier No. 8, Locust Point, Baltimore, Md.; the Wabash Pittsburgh Terminal Railroad freight house at Pittsburgh, Pa. It has also made further study of the use of electric trucks and other appliances.

TELPHER SYSTEM IN FREIGHT HOUSE AT ST. LOUIS.

Missouri, Kansas & Texas Railroad.

The Committee attaches two plans, Figs. 1 and 2, which will explain references made in this report.

The freight house has two floors. Wagons drive in from the Broadway (Street) level, stopping at a convenient point along the wharf or platform for unloading. Heavy articles, such as safes, boxes, etc., are handled from wagons to platform or to the trucks by jib cranes. After receipt of freight on the platform, it is loaded into trucks or package holders specially designed to be picked up by the overhead electric trolley or telphers and dispatched through one of the numerous hatchways to any one of the cars which are standing on tracks in the lower story. These trucks have a capacity of two tons. The telphers are equipped with two motors, one for traveling and one for hoisting. The maximum speed for traveling is 500 ft. per minute, maximum speed for hoisting 60 ft. per minute, and for lowering 120 ft. per minute.

The trucks are landed on platforms between the cars in the lower story, where the telpher is detached, the truck being pushed by hand to the door of the car which is to receive the freight. It was the intention that these trucks should be run into and turned within the cars, thus requiring the minimum labor in unloading and stowing the freight, but this is not now done.

For inbound freight the process is reversed. The trucks are loaded from the cars, pushed to a point immediately under any one of the hatchways, through which they are raised by the telphers and conveyed to any part of the upper platform at the driveway level. Pneumatic tubes convey the way bills from several posts on the freight house floor to billing offices on the third floor. All teams, teamsters and goods are housed in from the heat, cold and rain. The freight handled is package freight, such as is hauled in less than carload lots, and includes the usual diversified matter offered for railroad shipment. The packages are weighed, sorted and checked in the usual way on the upper floor.

The lower or track floor contains twelve tracks with total capacity of 117 cars, with island platform between adjacent pairs of tracks. The upper or wagon floor at the street level contains four driveways, 38 ft. wide; two platforms, 42x217 ft.; two platforms, 82x230 ft. The wharfage is 1,600 ft. There are 17 jib cranes and 35 automatic scales.

As originally constructed, there were 43 hatchways provided for the hoisting and lowering of freight between the two floors, but since the house has been in operation all but 22 of these hatchways have been closed, due to insufficient floor space.

The daily duty required at this station is approximately as follows:

(1) To handle one million pounds of outbound freight per day for loading into 77 cars.

(2) To handle a considerably less amount of inbound freight, the outbound freight being mostly handled in the afternoon and the inbound freight mostly handled in the morning.

The telpher system is carried overhead of the second floor, the building being designed for additional stories above this in case of future need. The supporting of this telpherage system necessitates heavy construction, which is correspondingly expensive. The telpher track system is arranged in loops, running at right angles to the tracks in the lower story, these loops being connected to a belt track extending around the four sides of the house. The movement on the belt track is generally in the same direction. The switches are operated by motors, and their operation is controlled by the motorman of the telpher. The position of the switches is indicated by signal lights.

The equipment consists of 16 telphers of 2 tons carrying capacity, 2 telphers of 6 tons carrying capacity, and 100 of the detachable trucks or package holders on which the freight is transported. Each telpher requires a motorman.

The construction of this two-story freight house on a limited area was necessitated by the Missouri, Kansas & Texas Railroad having to vacate its old freight house, which was leased, and its being unable to secure at the present site sufficient ground at reasonable cost to accommodate tracks and freight handling platforms on the same level. The cost of this installation is, of course, very high and could be justified only by such limitations as above mentioned.

The cost of maintenance of the telpherage system is considerable. In this particular case, however, it was due to the first installation of the overhead rail being soft, necessitating its renewal with a harder grade of steel. Along with the rapid wear of the rail originally installed it was noticed there was more or less injury to the eyes of the employes on account of fine particles being ground off the rail and falling through the air. It has further been found that considerable damage to freight is likely to result—more than results from the ordinary handling of freight. This is due to crushing by heavy loading on the trucks and on account of the motorman dropping loads with too great force. It has been found in practice that the trucks cannot generally be loaded to their full capacity without frequent rehandling, which is impracticable on account of not sufficient freight destined to a particular car being assembled for loading in its immediate vicinity.

There has been greater difficulty in preventing freight going astray as the result of two sets of men handling the freight on the two floor levels and no check between them.

It is further impracticable to avoid a great many empty runs with the telphers to bring back empty trucks, by reason of the fact that when a loaded truck is deposited through a hatchway no empty truck can be placed at the same point to be picked up at that time, and the telpher has to return later to pick up the empty truck from that same hatchway. There is a hazard of personal injury to truckers compelled to work under the trucks while being conveyed, due to the liability of packages falling therefrom. It has developed that there is likely to be considerable idle time of employes, resulting from difficulty in so distributing the freight as to have trucks at all times at the several cars ready for unloading as soon as the trucks previously delivered have been emptied. There is more supervision required to check against idleness and also against pilferage. A repair force at considerable expense is required for the maintenance of the electrical equipment, even at the present time, when the installation is comparatively new, and the cost of maintenance is

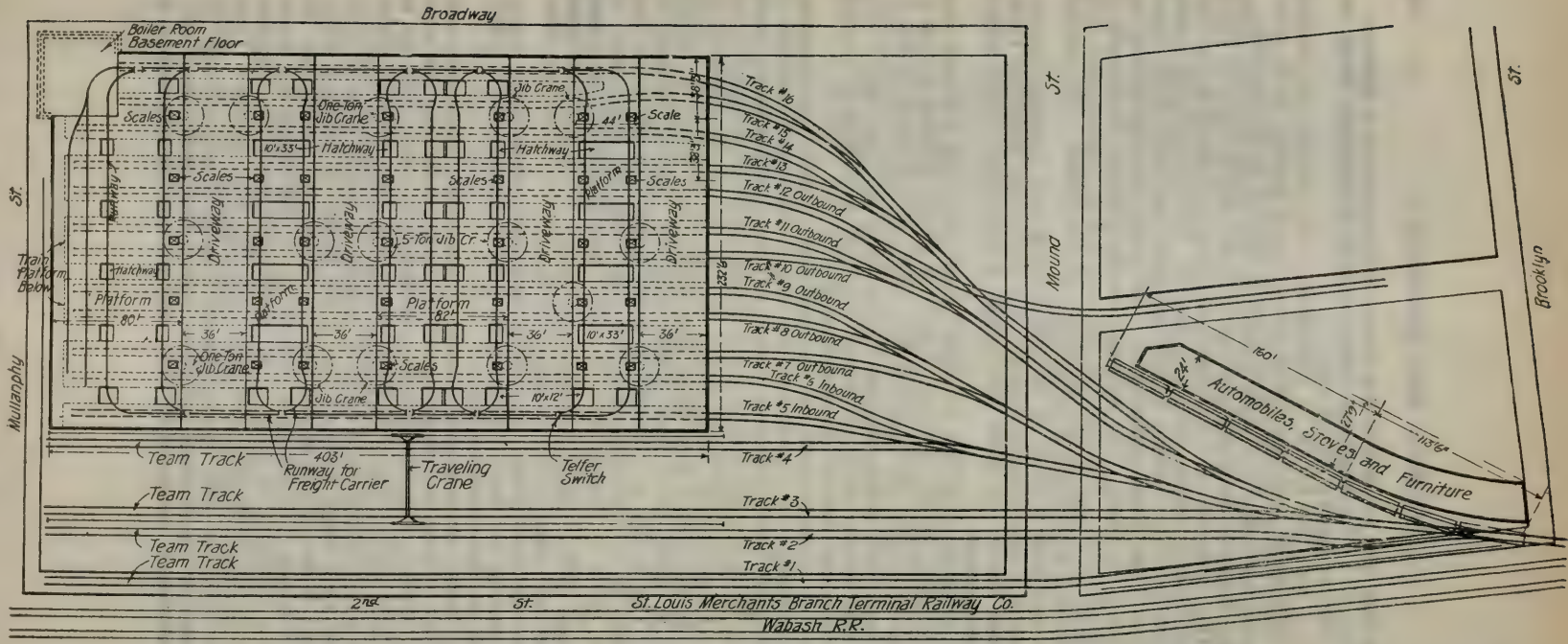


FIG. 1—GENERAL PLAN OF TRACKS, PLATFORMS, DRIVEWAYS AND TELPHER RUNS, ST. LOUIS FREIGHT HOUSE, MISSOURI, KANSAS & TEXAS RAILWAY.

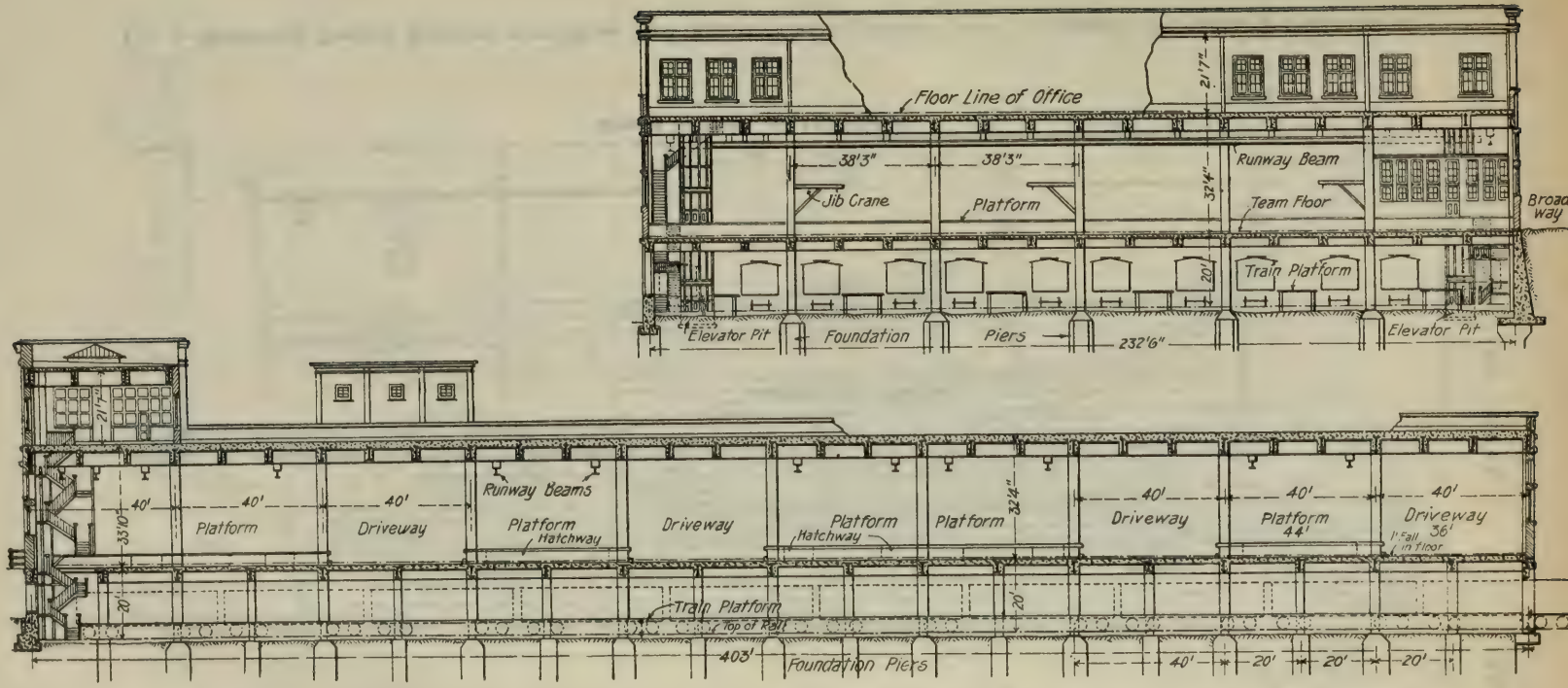


FIG. 2—GENERAL LONGITUDINAL AND CROSS-SECTIONS OF THE ST. LOUIS FREIGHT HOUSE, MISSOURI, KANSAS & TEXAS RAILWAY.

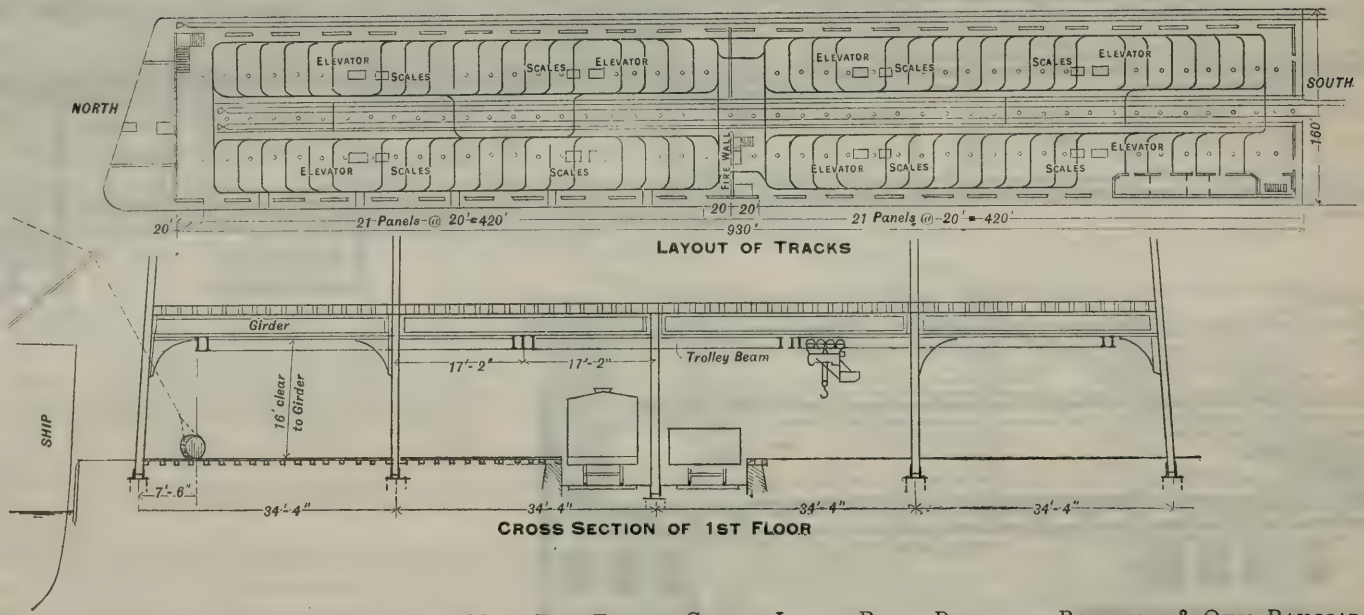


FIG. 3—METHOD OF FREIGHT HANDING WITH MONO RAIL ELECTRIC CRANES, LOCUST POINT, BALTIMORE, BALTIMORE & OHIO RAILROAD.

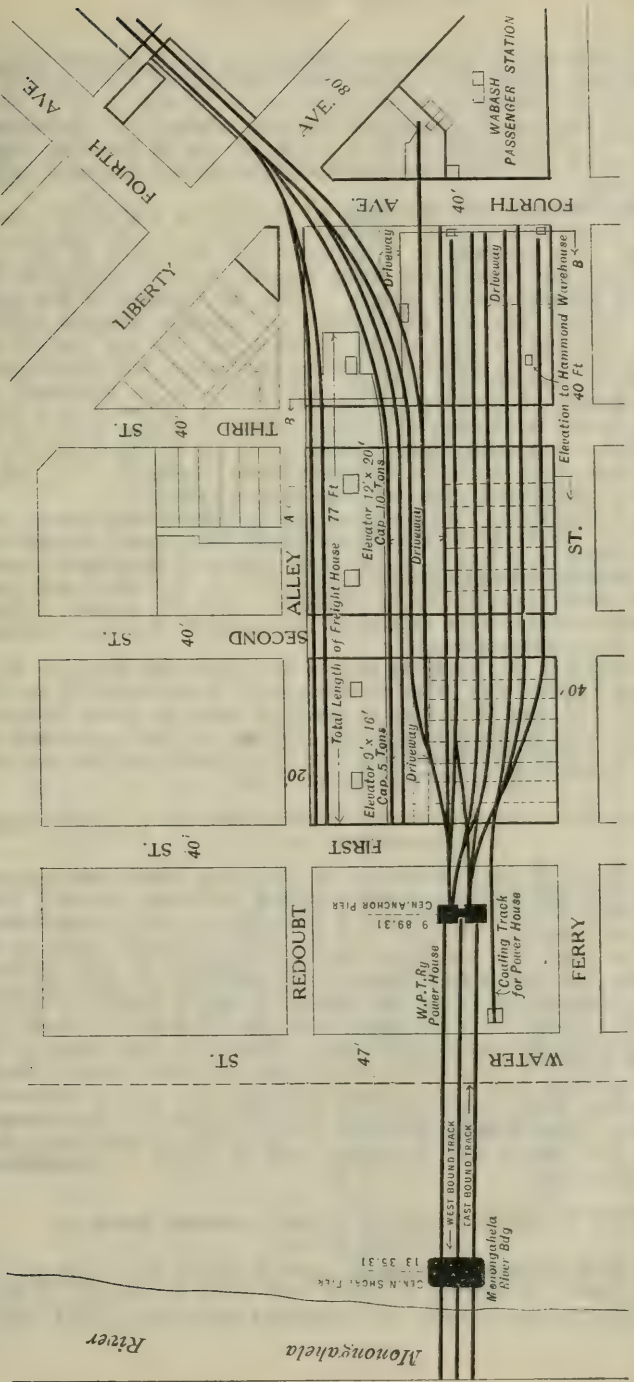


FIG. 4—PLAN OF TERMINAL SHOWING TRACKS AND WAREHOUSE, WABASH-PITTSBURG TERMINAL RAILROAD.

expected to increase in considerable measure as the equipment becomes older and more worn. The manual labor required in the handling of freight has been demonstrated by experience to be necessarily about as great as the handling of freight on one level without any intermediate mechanical handling, as the result of which the cost of handling freight by this system is materially, and apparently unavoidably, increased, rather than decreased.

It is probably true that the design of the buliding and of the telpher equipment could be improved, involving less first cost and less maintenance cost. It is naturally to be expected that this would be the case on account of this undertaking being entirely novel as applied to the handling of less-than-carload freight. While the working of this plant seems to indicate that the practicability of handling less-than-carload freight is questionable, there is no question but that the use of the telpher for any certain commodity can be successfully and economically worked where elevation and distance are factors to be considered, or where, regardless of classification, freight is to be delivered at a common point, as for the loading of a vessel. This is further borne out by the fact that a successful telpher system is in use by the Baltimore & Ohio Railroad on its Pier No. 8, Locust Point, Baltimore, Md., where miscellaneous freight is transferred from cars to vessels.

It was expected that the capacity of this St. Louis freight house, with its equipment, would be greatly in excess of the present demand for handling freight, or at least could be made capable of handling a greatly increased amount of freight simply by the addition of telphers and men. But it has been demonstrated by experience that the present volume of traffic about measures the capacity of this plant for handling classified frieght, which is a disappointment.

As explained in the foregoing part of this report, the Missouri, Kansas & Texas Railroad was forced to quick action in the nature of providing facilities and was limited as to space in order to obtain desirable location. It is to be complimented for making the bold experiment at a very heavy cost of installation, and it is to be hoped that they may yet find a way of attaining economy in its operation.

BALTIMORE & OHIO RAILROAD—TELPHER SYSTEM—PIER NO. 8, LOCUST POINT, BALTIMORE, MD.

Fig. 3 shows the arrangement of the telpherage tracks and a cross-section showing the position of the overhead telpherage carrier. This plant consists of 10 carriers of 2 and 4 tons' capacity, with 4 longitudinal tracks the full length of the pier—930 ft.—and cross-tracks every 20 ft. Switches for these are manipulated by the operator in each telpher. Freight from flat cars is taken directly and delivered at door openings in the pier shed, where it can be reached by ship's tackle. In taking freight from box cars it is necessary to handle it on trucks, which can be readily pushed into and out of cars. Then it is taken hold of by telpher and delivered for storage or in reach of ship's tackle. These trucks are equipped with ball-bearing wheels. As only certain commodities are handled at this point, sufficient saving is effected by the arrangement to more than warrant the cost of installation, maintenance and operation. This freight, also, is handled without respect to classification at the delivery point.

WABASH PITTSBURGH TERMINAL RAILROAD—FREIGHT HOUSE AT PITTSBURGH, PA.

Fig. 4. is a drawing showing the general design and character of this freight house. It extends in length over three city blocks, so that there are three separate houses on the ground floor with private team-

FIG. 4A.—FREIGHT HOUSE AND TRAIN SHED, WABASH-PITTSBURG TERMINAL RAILROAD.

ways between and along each side. The second, third and fourth floors are continuous across Second and Third Avenues (public streets) and also extend over a private side driveway. The fourth floor, 45x575 ft. and 44 ft. above street level, is at the track level. The first floor is used exclusively for receiving and handling freight to and from wagons, the second and third floors for the storage of freight only, and the fourth floor for the receipt and delivery of freight to and from cars. Freight is transferred between the different floors by five Otis hydrulic elevators, four of which have capacity of 10,000 pounds each and one of 20,000 pounds. The latter accommodates nine of the four-wheel freight trucks.

Inbound freight from cars is loaded on these four-wheel trucks, run onto elevators at the fourth floor, lowered to the first floor and delivered to wagons from that floor. No freight is removed from the trucks until delivered either to wagons or in storage, unless held in storage a considerable length of time.

They have in use 228 four-wheel and 56 two-wheel trucks. The cost of furnishing power and maintaining these five elevators, including pumps, pipe-lines, etc., is as follows:

Cost of elevators in place	$32,000.00	
Proportion of power house equipment, pipe-lines, etc.	8,000.00	
Total investment		$40,000.00
Interest allowance, 5 per cent. per annum	2,000.00	
Depreciation allowance, 4 per cent. per annum	1,600.00	
Maintenance cost per annum, labor and material	1,920.00	
Total charges per year	$ 5,520.00	

Total cost to operate per month, $460.

As a general idea of the capacity of this freight house, as compared with others, it was noted that one man handles an average of 1½ cars of freight per day; that is, a force of 20 men can handle 30 cars, or 40 men can handle 60 cars per day through this house. The freight house construction and equipment is of permanent, fireproof design, but involves no extra cost for any special installation, such as was observed in the telpher system in the freight house of the Missouri, Kansas & Texas Railroad at St. Louis.

ELECTRIC TRUCKS.

Four-wheel platform motor trucks have been introduced in a number of cases to replace the ordinary two-wheel trucks, the former having greater carrying capacity and higher speed than the latter. The truck system has the advantage of flexibility of movement with no fixed routes, as where carrier or telpher systems are used, and no investment for fixed plant, while it may be tried and introduced in existing freight houses without trouble.

The Delaware, Lackawanna & Western Railroad is using several storage battery one-ton trucks of this kind (Sprague and General Electric systems) at its transfer station at Secaucus, N. J., where freight brought in cars from various collecting stations in New York is transferred to cars for the outbound local and through trains. The transfer station has two pairs of tracks for the transfer cars, two for local cars, and two for through cars, these being separated by three platforms 900 ft. long (23 cars) and about 22 ft. wide. The trucks are 72x44 in., with the floor 22 in. above the rail and a motorman's platform at one end with con-

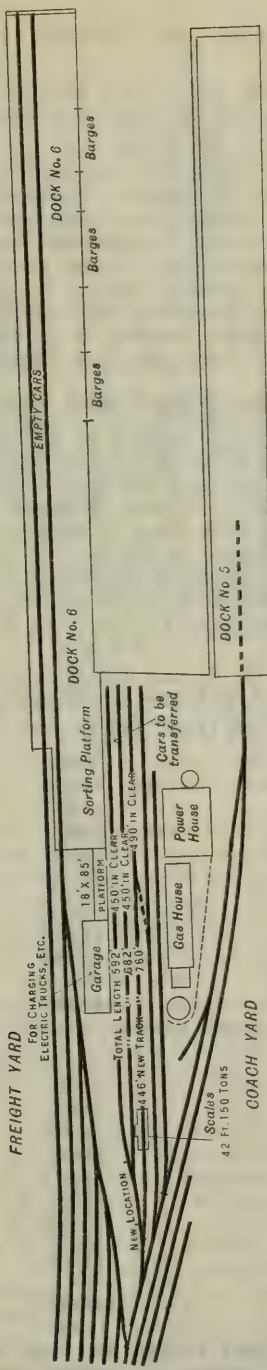


FIG. 5—PLAN OF DOCK NO. 6, ERIE RAILROAD, JERSEY CITY.

troller, brake and steering gear. They have electric bells to warn the truckers and other men, and can move at a speed as fast as ten miles per hour. The trucks are run directly into the cars, over steel bridge plates placed at the doors, and in this way pass to cars on the second track from the platform. Current is supplied from a line supplying the yards and is converted to the necessary voltage by a small plant on one of the platforms. This transfer house with electric truck service is described in further detail in the "Engineering Record" of Sept. 21, 1912.

ERIE RAILROAD—ELECTRIC TRUCKS AT DOCK NO. 6 JERSEY CITY, N. J.

Fig. 5 is a drawing showing trackage arrangement serving docks. The following information is given by Mr. William C. Carr, president of the Automatic Transportation Company, in an address on the "Mechanical Handling of Freight" before the New England Railroad Club, Feb. 13, 1912:

> "The following tabulated figures of the operation of the Erie Railroad at Jersey City for three months, call attention to the savings that have been effected by the use of the electric trucks in combination with the two-wheeled trucks, and I desire to call attention to the fact that the figures which we worked against had been reduced by the most strenuous activity on the part of the Erie's officers from about 47 cents per ton to about 40 cents per ton. Notwithstanding this fact, the introduction of the electric truck made surprising reductions in the best figures that could be accomplished by the old methods:

COST OF HANDLING FREIGHT AT DOCK NO. 6, JERSEY CITY TRANSFER, ERIE R. R.

Comparison of the cost during period that storage battery trucks were in use, with same period year previous.

With Hand Trucks—1910.

Month.	Tons.	Cost.	Cost per ton.
April	15,252	$6,015.97	$0.394
May	14,872	5,727.07	.387
June	15,812	5,979.77	.378
July	15,083	5,801.88	.385
August	16,102	6,190.32	.384
September	16,041	6,289.75	.392
October	16,956	6,615.10	.390
November	15,506	6,142.03	.396
December	14,786	5,896.44	.399
Total	140,410	54,658.33	$0.389

With Storage Battery Trucks—1911.

	Tons.	Cost.	Cost per ton.
April	13,640	$ 4,418.88	$0.324
May	13,829	4,165.11	.301
June	14,382	4,128.30	.287
July	13,517	3,888.05	.286
August	14,426	4,129.29	.286
September	14,877	4,191.73	.282
October	15,095	4,305.72	.285
November	14,312	4,268.99	.298
December	13,000	3,934.19	.303
Total	127,078	$37,410.35	$0.294
Decrease	13,332	17,247.98	.095

NOTE—The above cost in 1911, with storage battery trucks, includes running repairs, viz.: material, current and electricians.

COST OF HANDLING AT DOCK 6.

Fiscal year.	Tons handled.	Total cost.	Cost per ton.
1903-4	151,626	$72,024.60	$0.475
1904-5	147,274	66,095.96	.448
1905-6	143,277	64,621.35	.451
1906-7	150,930	70,881.35	.47
1907-8	143,239	65,559.04	.458
1908-9	145,832	55,372.64	.38
1909-10	171,983	62,697.83	.365
1910-11 (1st 9 mos.)	137,435	53,618.43	.39

"These figures were compiled and published by the "Engineering Record" in the issue of January 6, 1912, the information being furnished by the Erie management in an entirely disinterested way, simply as a statement of facts of interest to all engaged in transportation. The saving of the Erie Railroad for the first thirty days was $995.00. The savings were increased as the efficiency of the force improved by experience with the trucks.

"The railroad company has reduced (August, 1911) the common laborers from 100 to 37. It has been necessary to add to the force the requisite number of men to operate the machines. These men have been drawn from the ranks of common labor previously engaged and educated in the handling of our trucks. They have become proficient in a surprisingly short time. Naturally enough, this limited number of men have been paid additional wages.

"The introduction of the trucks has also necessitated the adding to the force of two electricians, one for day and one for night, and a common laborer as a helper. The total force engaged in the month of August, 1911, including laborers, checkers, callers, foremen, clerks, motormen, sealers and coopers, was 77 men against 126 in 1910.

"Let me call special attention to the figures which show that there is a reduced tonnage in 1911 of 1,676 tons, or 10.4 per cent. Notwithstanding this fact, the cost per ton of handling freight was reduced 25 1-9 per cent. Any man who has had charge of transportation methods knows that with reduced tonnage it is considered almost impossible to make a corresponding reduction in fixed charges. During this month the saving was $1,416.63. Figures for the month of September: The interesting points here are: 39 common laborers as against 112. A complete force of 79 men as against 137. During the month of September, 1911, there was a reduction of 1,164 tons against the previous year, or, in other words, 7.2 per cent. less tonnage. Notwithstanding that fact, the cost per ton shows a saving of 28 per cent., as compared with the old methods. A saving of $1,640.93.

"During the month of October there were employed 38 common laborers, as compared with 115 the previous year, a total force of 79 against 140, and a reduction of 1,861 tons, or 11 per cent., reducing the cost per ton 26.9 per cent. A money saving this month of $1,583.47.

"I believe, in making an off-hand estimate, it would be an easy matter for you to satisfy yourselves that these trucks are capable of showing a 33 per cent. saving under normal conditions with ten per cent. increase in business."

Mr. Geo. W. Brown, of the Elwell-Parker Electric Company, gave some figures at the same meeting, which, he stated, one of the large rail-

road systems had compiled on a test during the month of September, 1911. These figures are the daily averages over the period of one month with the use of two trucks and show how this was accomplished, together with some interesting points. His statement is as follows:

"All of these figures represent the average hours in service for a day—eleven hours—a daily average for the 26 working days. The mileage of these two trucks was 13.6, the tonnage they handled, 225; the average tonnage per hour, 20.3; the total number of loads, 230; the average length of haul in feet, 158.5. Of course, that is a little low on account of this New York pier being quite up-to-date, and where we were able to cut down the length of haul more than they would be on the piers that are out-of-date. The average number of pieces per load amounted to 29.8, the average weight per piece in pounds, 88.5. The average time per load in minutes, that is, loading, unloading and the running time, amounted to 2.89 minutes. We think that was very fair, considering the amount of time it takes to get into a car, get your load on, take it to the pile or to the boat and return; the round trip. That means the running time and the loading and unloading.

"The average time to load amounted to 58 seconds flat. The average time to unload amounted to 60.3 seconds. The number of men in this gang was 8, that is, two men on the trucks, three men in the car and three men on the pile. I think that the number of men could be cut down at least two men—taking one man from the car and one man from the pile; this would give them six men to their gang. The tonnage for one gang, that is, tonnage credited the gang for paying them on the tonnage basis, amounted to 247 tons. This is in accordance with Mr. Carr's statement that there is not any electric truck that can be got up that will ever take the place entirely of a two-wheeled truck. There are places that you cannot get an electric truck, or any four-wheeled truck, and this difference, the tonnage of 225 for the electric truck and 247 tons for the gang, is accounted for in this way, as there was some tonnage handled by the two-wheeled truck that could not be handled by the electric truck. Paying these men on the tonnage basis, they made $2.40 a day; this was too much money for that class of labor, so they are going to cut the rate down. This is the first month on the test, so necessarily it was experimental. The cost of labor amounted to 8.7 cents per ton. The cost of maintenance we have figured at 3.9 mills. We could not get that through our freight trucks, but the railroad that made this test has had our baggage trucks in operation for a period of seven years, and we have taken that maintenance cost for the operation of these baggage trucks from their statistics and from their record for a period of seven years.

"I am now going to give the monthly totals of these figures, just to let you realize what can be done with two trucks:

Total number of days operated	26
Hours of actual operation	286
Mileage for the two trucks for the month	353.6
These two trucks handled in the month (tons)	5,850
They carried (loads)	5,980
Number of pieces in round figures	174,000

"Summarizing their cost, we get 8.7 cents per ton for the labor, approximately 4 mills for power.

"I will also say that on baggage truck operation in the month of April, with 52 trucks in operation, at the Pennsylvania

Railroad station in New York, the cost per ton was 89 cents per truck per month, which is very low indeed, considering the mileage they cover. This is based on using their own power, figuring about 2½ cents per kilowatt hour. The maintenance cost, as I have said before, we figure about three mills over the record of six years' maintenance on a number of these baggage trucks. We could not get it on the freight trucks, as we have not had long enough time to find any maintenance on them at all as yet. We figure the depreciation there is 9 mills, that is, depreciation and the interest on the investment, so that their total cost for handling of freight on this pier amounted to approximately 10½ cents per ton."

Mr. W. P. Coria, of Baltimore, Superintendent of Agencies of the Merchants' and Miners' Transportation Company, gave some figures in the practical operation of 20 electric trucks, which are now in use at the Savannah terminals of this company. He stated that labor units have been reduced about 25 per cent. to prevent waste, as one electric truck will carry approximately five times the load of one hand truck. He further stated as follows:

"I will give you some figures prepared after the trucks had been in operation about four weeks. I have taken 13 electric truck loads and 13 hand truck loads of the same commodities, traveling the same round-trip distance.

"The average weight of the electric truck load was 1,531 pounds, distance 748 feet, time 5 minutes and 23 seconds, average feet per minute 138.

"The average weight of the hand truck load was 400 pounds, time four minutes and 46 seconds, average feet per minute 156.

"I want to explain the average time we made by cutting out one electric truck and one hand truck. The electric truck made seven stops, distributing the package freight around the houses. The hand truck made but one stop, which makes the average feet per minute for the electric truck 148 and reduces the hand truck speed to 148, which is the same. This shows a difference of 383 per cent. in weight in favor of the electric truck, while the time was 11.3 per cent. in favor of the hand truck. The per cent. figures are based on the 13 loads.

"Reducing this to tons, the electric truck carried about 8 tons per hour, compared with 2½ tons by the hand truck.

"These averages were, of course, made with individual loads, and this record could not be made with one truck working continuously, as there would naturally be a percentage of time wasted between the truck loads. All of this freight was handled from ships' hatches to freight houses and into cars.

"At Savannah we have merchants' warehouses located in the outlying districts of the yards, and the freight that I will now refer to is first handled from the ship to the freight houses waiting orders of the merchants. The work these trucks perform is taking freight from the freight houses to the warehouses, the average trucking distance being 1,107 feet. This work was performed for a fraction over 9 cents per ton, while the hand trucks on similar work produced a cost of 17 cents per ton, a saving of about 47 per cent. in cost. With the hand trucks we work 18 men, compared with 6 men on the electric.

"The average trucking distance at our Savannah terminal, from the center of the main discharging berth to all of the warehouses, is 637 feet. The varying tides produce grades from the ships' upper decks to the pier surface of from 37 per cent to

zero, and many other conditions prevail there, such as labor, rail connections, variety of ships and cargoes, etc., which prompted us to select that terminal as the most practical of all the ports touched by our line, for a severe test, and I can say that they have had it. If any tool ever got a test, they have had it at Savannah.

"Our incline drop elevators are worked successfully in connection with the electric trucks, but are used for power economy alone, as the trucks only require assistance, when taking the maximum 37 per cent. grade. These elevators were primarily installed to assist hand trucks with their loads up heavy grades. Up to the present time we have found it possible to handle 70 per cent. of the freight with the electric truck, and on the balance, or 30 per cent., it is necessary to employ hand trucks; thus the full efficiency of the electric truck is not obtained on cargo work. The cost for current during the entire period since trucks have been in operation has averaged about 11 cents per day per car."

The electric trucks of the Automatic Transportation Company have been used also for handling mail and baggage at passenger stations; for freight service they have been installed by the following railroad and steamship lines in addition to those already mentioned:

Chicago, Rock Island and Pacific Railroad.....Silvis, Ill.
Seaboard Air Line Railway.....Portsmouth, Va.
Panama Railroad.....Colon, Panama
Boston Terminal Company.....Boston, Mass.
Baltimore Steam Packet Company.....Norfolk, Va.
Old Dominion Steamship Company.....New York and Norfolk, Va.

Another type of storage battery truck, built by the Cleveland-Galion Motor Truck Company, has been used experimentally in the freight station of the Lake Shore & Michigan Southern Railway, at Cleveland, Ohio. This is described in the "Railway Age Gazette," October 11, 1912.

Also the Elwell-Parker storage battery truck has been used by the Illinois Central in the handling of cotton at Stuyvesant Docks, New Orleans.

MISCELLANEOUS.

In addition to the above, we find some roads and steamship companies are using inclined elevators, overhead jib cranes, stacking or elevating conveyors, briefly described as follows:

Inclined Elevators.

There is a somewhat extensive use of inclined elevators at piers to assist the moving of loaded hand trucks on the inclines between ships' decks and the pier floor. Some of these are traveling platforms, which carry the men and the trucks. Others are simply endless chains which have lugs to engage the axles of the trucks and push them forward, the men walking the ordinary way. The Otis Elevator Company has built a number of installations of the latter class and some of the former class (all on the Reno patents). The installations of the chain type include piers of the Boston & Maine Railroad at Boston; the New York, New Haven & Hartford Railroad at Bridgeport, Conn.; the Merchants' & Miners' Transportation Company at Savannah, Ga., and the Metropolitan Steamship Company at Boston. Each of these has two electrically operated machines, except that the last has three machines. It is stated that the last named company estimates a saving of $33,000 in handling its freight for one year, which is approximately six times the cost of the machines. Each machine can handle from 600 to 1,900 trucks per hour, according to the speed of the chain.

Overhead Jib Cranes.

A type of crane which is used extensively in freight houses in Great Britain is a combined traveling and revolving overhead crane. Instead of the usual hoisting trolley on the bridge of the crane, the trolley has suspended from it a frame which carries a horizontal boom or jib, and this frame can be revolved through a complete circle. The freight house of the Great Western Railway at Cardiff, Wales, has a Babcock & Wilcox electric crane of this type; its bridge has a span of 50 feet, and the boom on the traveling trolley has a working radius of 18 feet. The hoisting capacity is one ton, and the speeds are as follows:

Bridge travel	250 feet per minute
Trolley travel	120 feet per minute
Swinging	230 feet per minute (at end of boom)
Hoisting	30 feet per minute

The new freight station of the North British Railway at Glasgow, Scotland, has fifteen overhead traveling cranes for unloading cars. These are of the revolving jib type mentioned above, the jib being 23 feet long, but the trolleys run on narrow parallel runways instead of upon a traveling bridge. Two of these are three tons and the other 1½ tons hoisting capacity. Each of the latter has a 17-hp. motor for hoisting at 100 feet per minute, one of a 2-hp. for swinging at two-thirds of a revolution per minute, and one of 4½ hp. for traveling at 360 feet per minute. For hoisting freight from cars to the upper floors of the warehouse, there are two traveling trolley hoists on each floor, with three wells or shafts for interior hoisting, while the top floor has a 1½-ton trolley carrier or helper. There are also six elevators at one side of the house. For handling heavy freight, there is a gantry crane, having one end of the bridge supported by a leg with wheels riding on a rail laid on the ground level, while the other end is carried by wheels on a runway built on the freight-house wall. The bridge is of 50-foot span, and carries a traveling hoist of 40 tons capacity. The bridge has a travel of 200 feet along the front of the freight house and into the yard.

Stacking or Elevating Conveyors.

In pier sheds, cotton sheds, storage warehouses, etc., it is often desirable to stack goods (in bales, sacks, boxes, etc.) to a considerable height, in order to save floor space. Sometimes an overhead traveling crane, or traveling bridge with hoisting trolley, may be installed for this purpose. In many cases, however, a portable machine would have a greater range of usefulness, and several portable elevating and conveying machines of this kind have been installed by the Brown Portable Elevator Company. These installations include the stacking of grain and sugar in sacks, stacking hay in bales, and also handling miscellaneous materials and freight. One installation is for the Central Railroad of Georgia, at Savannah, Ga., for piling bags of material on a pier. The conveyor is carried on a steel frame mounted on a wheeled truck, on which is mounted also the motor and driving mechanism, and this frame can be adjusted to any desired inclination and height. In some machines there is a separate carrier on each side of the truck, so that one may be inclined to raise material from the floor to the heel of the other conveyor, this latter being adjusted to a horizontal or inclined position, according to the point to be reached. These machines are described in an article in "Engineering News," September 28, 1911, in which it was stated that: "The use of portable conveyors presents many opportunities for economy and efficiency in the handling of freight at warehouses, stores, railway freight and steamship piers, etc."

FREIGHT HANDLING EQUIPMENT FOR DOCKS AND STEAMSHIP TERMINALS.

Some freight handling installations at piers have been mentioned above, but in crane equipment for handling ship cargo American ports are notably behind European ports. At the former, reliance is placed mainly on the ship's winches and cargo booms, which can handle material only directly alongside. In European practice there are usually numerous traveling cranes along the quays and sheds. The tower type of crane is a jib crane on a tower mounted on wheels to run on tracks along the piers or docks. The portable type of crane is mounted on a steel tower traveling on a track of wider gage than that of a railway track, and made open so that cars can run beneath the crane, and the crane can move from point to point without interfering with car on the track which it straddles. A semi-portal or semi-gantry crane may span the width of quay between the freight house and water; the outer end of the bridge is supported by a leg traveling on a rail near the edge of the quay, while the inner end is carried by wheels riding on an elevated runway on the freight house, like a traveling crane. On the tower or bridge is a revolving jib crane, which may be fixed in position or may traverse along the bridge. In many modern installations, the cranes travel on the roof of the pier or warehouse, so that they handle cargo between ship, car or warehouse without obstructions to the tracks or driveways between the house and the ships. Several crane installations of these types were described in "Engineering News" of September 12, 1912.

The rail and water terminals at Texas City, Tex., on the mainland side of Galveston Bay were described in the "Railway Age Gazette" of July 12, 1912. The main pier is 1,400 ft. long and 1,000 ft. wide, with four parallel warehouses: 80x1,120 ft., 118x520 ft., and two 100x750 ft. On shore there are four warehouses in line: One 75x1,000 ft. and three 100x250 ft. One warehouse is equipped with three overhead traveling cranes and an electric conveyor along the floor extending the full length of the building. On one side of the dock are two traveling gentry cranes about 120 ft. long, with hoisting trolleys on the bridge. The inner end of the bridge extends over the warehouse roof, the alternate panels of which are removable so as to form hatchways. The outer end of the bridge projects beyond the dock line, so that freight can be handled directly between the ship's hold and the warehouse.

A paper on "Cargo transference at Steamship Terminals" was read before the Society of Naval Architects and Marine Engineers, at New York in November, 1911, by Mr. H. McL. Harding. He also described plans for a new steamship terminal in New York harbor, at Staten Island, in "International Marine Engineering" of September, 1912, and in April, 1912, he made a report to the Commissioner of Docks at New York on the handling of freight at marine terminals.

Respectfully submitted,

YARDS AND TERMINALS COMMITTEE.

REPORT OF SPECIAL COMMITTEE ON GRADING OF LUMBER.

DR. H. VON SCHRENK, *Chairman;* B. A. WOOD, *Vice-Chairman;*
W. McC. BOND, W. H. NORRIS,
D. FAIRCHILD, J. J. TAYLOR,
R. KOEHLER, F. B. WALKER,
A. J. NEAFIE, *Committee.*

To the Members of the American Railway Engineering Association:

Your Special Committee on the Grading of Lumber held one meeting in St. Louis during the year, following discussions by correspondence. Numerous conferences had been held with committees of lumber manufacturers' associations. One of the aims of the Committee was to secure the actual adoption of the rules drawn up jointly by your Committee and the various lumber manufacturers' organizations. Your Committee can report this year that the standard rules for maintenance of way lumber adopted last year by this Association, when submitted back to the lumber organizations interested, were agreed to, with slight modifications, as follows:

For southern yellow pine, by the Yellow Pine Manufacturers' Association.

For hardwoods, by the Hardwood Manufacturers' Association of the United States.

For Douglas fir, by the West Coast Lumber Manufacturers' Association.

The Northern Pine Manufacturers' Association refused to accept the white pine rules. The acceptance of the rules adopted last year by the three associations referred to was made subject to slight modifications in the rules made since the time when these rules were first proposed. These modifications are so slight, however, that your Committee believes that they can be readily adjusted in individual cases.

Your Committee has been engaged in making further studies of rules for classes of lumber not included in the rules already adopted. These considerations are well under way, and it is expected two or three additional sets of rules will be ready for submission next year.

Consideration has also been given to the grading rules for cypress, submitted for information last year. (See Bulletin No. 144; Vol. 13, 1912, pp. 875-884.)

RECOMMENDATIONS.

Your Committee recommends that the lumber grading rules for cypress, as published in Appendix E, Bulletin No. 144 (Vol. 13, 1912, pp. 875-884), be adopted as standard.

Respectfully submitted,

SPECIAL COMMITTEE ON GRADING OF LUMBER.

REPORT OF COMMITTEE I—ON ROADWAY.

W. M. DAWLEY, *Chairman;* — J. A. SPIELMANN, *Vice-Chairman;*
J. R. W. AMBROSE, — C. S. MILLARD,
JOHN C. BEYE, — W. D. PENCE,
WARD CROSBY, — A. C. PRIME,
W. C. CURD, — H. J. SLIFER,
PAUL DIDIER, — JOHN G. SULLIVAN,
R. C. FALCONER, — F. L. WHEATON,
S. B. FISHER, — J. E. WILLOUGHBY,
FRANK MERRITT, — W. P. WILTSEE,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Roadway has had under consideration during the past year the four (4) subjects assigned by the Board of Direction, and respectfully submits its report.

A meeting of the Committee was held at Chicago, Oct. 4, 1912, and a joint meeting of representatives of the Track, Signals and Interlocking and Roadway Committees was held at Buffalo, November 12, to decide the separate phases of the subject of Economics of Roadway Labor, which should be covered by each of these Committees.

Four Sub-Committees were formed to consider the subject assigned to your Committee.

(1) Present formulas of general application for determining waterway areas under varying conditions, including consideration of hydraulic features: W. D. Pence, Chairman; John C. Beye, A. C. Prime and W. C. Curd, Sub-Committee.

Considerable space has been given to the subject of waterway areas in the Association Bulletins and Proceedings in recent years and somewhat favorable action has been taken tending to support the general practice of using formulas as an aid to the judgment in such work. Successive reassignments of this subject for committee work has been made by the Board during the past two years and some further progress has been made. It does not appear, however, that data can be had at this time which would justify a further attempt to derive a simple formula having general application.

On the subject of the hydraulic features of culverts considerable information has been collected, but owing to incompleteness of certain features, it is deemed advisable to defer the presentation till a later date in one of the Association Bulletins. Reference is again made to the valuable compilation relative to current practice in the determination of culvert areas in the Association Proceedings, Vol. 10, Part 2, for 1909, pp. 967-1022. In the discussions there given the hydraulic features receive considerable attention.

(2) Report on and recommend unit pressures allowable on roadbeds of different materials, conferring with Committee on Ballast: S. B. Fisher, Chairman; J. R. W. Ambrose, John G. Sullivan and C. S. Millard, Sub-Committee.

In Proceedings American Railway Engineering Association, Vol. 13 (1912), pp. 95 and 96, a list is given of articles published giving information and results of experiments made to determine the depth of ballast required to give a uniform distribution of pressure on the roadbed, the conclusion being that (with a tie spacing of 24 to 25.5 in. center to center) approximately 2 ft. of ballast is necessary to obtain uniformity of pressure parallel with the track. In all these experiments there is no definite determination of the amount of this uniform pressure.

The Chairman of the Committee on Ballast advises that "the determination of the proper unit pressure with any degree of accuracy and without guess work necessitates certain tests or experiments, and so far the Ballast Committee has not been able to find any information on this subject which has not already been given to the Association;" and your Committee on Roadway has failed to discover anything new on the bearing power of soils or on the magnitude of the unit pressures to be carried by the roadbed.

Under these circumstances your Committee can do no more than again direct attention to the following resolution heretofore submitted (see Proceedings, Vol. 13, p. 397):

"Resolved, That the Board of Direction be requested to set aside an appropriation and to appoint a Special Committee, consisting of members of the Roadway, Ballast and Track Committees, to make experiments to determine the magnitude and distribution of the load transmitted to the roadbed through ballast of various kinds and also to determine by test the bearing power of various materials under varying conditions ordinarily found in the construction of the roadway."

As the experiments should extend over a considerable period of time to cover seasonal variations and should be conducted under actual traffic conditions, the expense would be quite heavy and probably should be borne jointly by several of the larger railroad systems.

The present high percentage of rail failures together with the undoubted advent of the 100-ton car and the constant increase of locomotive axle loads make it imperative that some systematic study of the roadbed be made as a foundation for the track.

(3) Report on Tunnel Construction and Ventilation: Paul Didier, Chairman; W. P. Wiltsee, R. C. Falconer, F. L. Wheaton and Ward Crosby, Sub-Committee.

THE VENTILATION OF SUBWAY TUNNELS.

So far as known there is only one constituent of the atmosphere which is directly useful to living beings and this is oxygen. The other gases are not immediately necessary, although they perform many indispensable functions in the economy of nature.

The essential act of respiration is an absorption of oxygen and the production of carbon dioxide.

The principal gases of the atmosphere are present in a mechanical mixture and not in chemical combination with one another. A portion of the oxygen may be abstracted without affecting the other constituents and other gases may be added without affecting the oxygen. Oxygen

has always the same properties whether it is freshly prepared or not. Fresh air is simply air which is uncontaminated.

In the open country, upon the ocean and at all elevations, the proportion of the leading constitutents of unpolluted atmosphere are nearly constant.

Pure atmospheric air free from aqueous vapor may be taken to have the following composition, by volume (see Report of a Parliamentary Committee on the Ventilation of Factories and Workshops, London, 1902, p. 93):

Oxygen	20.94 per cent.
Nitrogen	78.00 " "
Argon	0.94 " "
Carbonic Acid	0.03 " "
Helium, Krypton, Xenon, Hydrogen, etc.	Traces
	100.00 per cent.

Included in this list, although not specifically mentioned, are gases of decomposition, principally ammonia and sulphur compounds, which, with varying proportions, are probably always present in minute amount.

According to Ramsay (Gases of the Atmosphere, London, 1905, p. 257), the rare gases mentioned in the foregoing table and recently separated from nitrogen are present to the following extent: Helium, 1 part in 245,300 volumes of air; neon, 1 part in 80,800; argon, 1 part in 106.8; krypton, 1 part in 20,000,000; xenon, 1 part in 170,000,000. The presence of ozone or peroxide of hydrogen is not without sanitary significance in a sample of air, for, owing to their energetic oxidizing properties, the presence of either gas may be taken to indicate the absence of organic matters. Pure air is odorless, colorless and tasteless. Odors are nearly always due to gases and not to solid particles. Aside from oxygen, the two gases which are of greatest interest in studies of ventilation are carbon dioxide and water vapor. No other normal gases of the atmosphere vary so much as do these two and none, under ordinary circumstances, has such an effect upon comfort.

The peculiar interest which attaches to carbon dioxide lies in the fact that it is a convenient measure of the extent to which air is vitiated by breathing, by lights and by fires. It is a product of respiration and of the combustion of fuel and at the same time varies little in uncontaminated air. There appears to be little difference between the amount present in pure country air, whether in forests or over the ocean.

From accurate analyses made in France by Reiset (Annales de Chimie et de Physique, Vol. 26, 1882, p. 198), who used samples of air measuring 525 liters each, 2.96 volumes of carbon dioxide per 10,000 volumes of air appears to be close to the normal for the country. Angus Smith reported that air among the Scotch hills contained 3.36; J. S. and E. S. Haldane (Physiological Magazine, 1890, p. 306) 3.0, and G. F. Armstrong, 3.13 for the country air of Scotland. Three parts may be accepted as sufficiently correct for most purposes.

Water vapor, not to be confounded with moisture in visible form to which the term vapor is so often applied, is always present in a normal atmosphere.

It is usual to refer to the presence of water vapor as humidity and to the ratio of the quantity present to the maximum quantity, which could be present at a given temperature as the percentage of relative humidity. Close to the ocean the relative humidity is generally in the neighborhood of 90 per cent., but in very dry places it may go below 10 per cent.

One of the most important facts to remember concerning the existence of water vapor in the atmosphere is that the greatest amount possible varies decidedly with the temperature. While at 0 degrees Fahrenheit, the greatest possible weight of a cubic foot of vapor is 0.54 grain, or 35 milligrams, at 80 degrees Fahrenheit, the maximum is 10.95 grains, or 709.56 milligrams.

The absolute humidity is the actual amount of vapor present expressed either in terms of its weight in a given volume of air or in terms of its expansive force. This expansive force is often called vapor tension. Its amount can be easily calculated when the relative or absolute humidity, temperature and pressure are known.

It is a well-known fact that the air of cities always differs somewhat in composition from the normal atmosphere of the country.

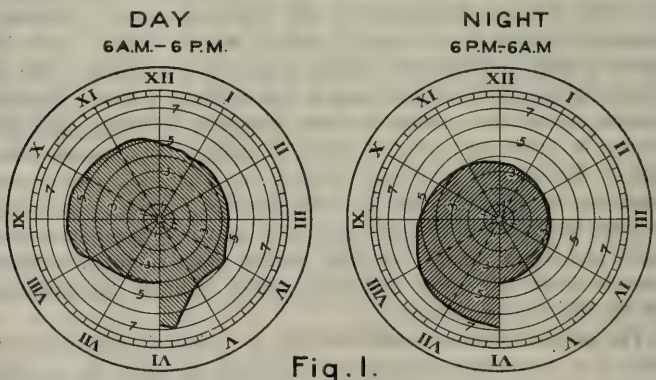


Fig. 1.

Variations in the amount of carbon dioxide in the air of the subway
Averages of 1244 analyses

Angus Smith, who found 3.01 volumes of carbon dioxide per 10,000 in the parks of London, found 3.80 in the streets. His average of samples from different parts of London was 4.39, from Manchester 4.03, from Perth 4.14 and from Glasgow 5.02.

The municipal laboratory of Paris has kept records of the amount of carbon dioxide in the air of Paris since 1890, with results as follows: In the center of Paris the annual average has been slightly higher than in the southern part. In the center it has varied from 3.06 to 3.44. In the South the minimum has been the same as in the center, but the maximum has not been so high. The monthly range has been 3.04 to 3.36 in the center. In both sections the greatest amount has occurred in November and the least in July.

VARIATION OF CARBON DIOXIDE IN THE AIR OF PARIS DURING THE DAY AND NIGHT, 1891 TO 1900, INCLUSIVE.

	Montsouris Park.	Center of City.
Day	3.10	3.34
Night	3.18	3.21
24 hours average	3.14	3.27

George A. Soper in observations made for the Rapid Transit Commission, of New York, found the amount of carbon dioxide to vary from hour to hour in the air of the streets of New York very much, as it varied in the air of the subway. It was highest at 6 p. m. and lowest between 1:30 and 3:00 a. m., with certain fluctuations through the day. The average of 309 analyses was 3.67.

The following table (Lehmann, Meth. Pract. Hy., 1901, p. 174) has been compiled from the reports of many investigators to show at what concentrations various common industrial gases are capable of producing immediate and observable effects upon health.

TABLE SHOWING CONCENTRATION BY VOLUME AT WHICH CERTAIN COMMON GASES CAUSE VISIBLE INJURY TO HEALTH.

Parts Per 10,000.

Name of Gas.	Rapid and dangerous injury.	Bearable for 30-60 min. without grave effects.	Trifling symptoms after action for some hours.
Hydrochloric Acid	1.5 to 2.0	.05 max. 0.1	.01
Sulphurous Acid	0.4 to 5.0	.05	
Carbonic Acid, per cent.	About 30.0	6 to 8	1 to 2
Ammonia	2.5 to 4.5	0.3	.1
Chlorine Bromine	.04 to .06	.004	.001
Iodine		.003	.005 to .001
Hydrogen Sulphide	0.5 to 0.7	.2 to .3	.1 to .15
Carbon Disulphide	.01	.002	.001
Carbon Monoxide	2 to 3	.5 to 1.0	.2

The difference between the principal gases in inspired and expired air is given by the following table taken from Foster (Text Book of Physiology, N. Y., 1906, p. 440):

	Inspired Air.	Expired Air.
Oxygen	20.81	16.003
Nitrogen	79.15	79.589
Carbon Dioxide	.04	4.38

From these figures it appears that there is little change in the nitrogen, but that the oxygen has been reduced about 4 per cent. and carbon dioxide increased by nearly the same amount.

Besides carbon dioxide, expired breath contains about 5 per cent. of aqueous vapor and various other gases, including slight amounts of ammonia, hydrogen and marsh gas. These are of little or no direct consequence in studies of ventilation.

The average adult takes into his lungs about 396 cu. in. or 6500 c.c. of air per minute and gives off the same amount of vitiated air which must be greatly diluted before it is generally considered suitable for further respiration. This is not saying that the carbon dioxide itself is dangerous to breathe even for a considerable period of time and in considerable concentration. It must be present to an extent 40 times that present when a room begins to smell stuffy and unpleasant before it produces any immediate effect and then there is merely an increase in the rate of breathing. Neither does an increase or decrease of 2 or 3 per cent. in the oxygen seem to produce any evil effect. Long before the air becomes so vitiated as this, however, other impurities from the lungs make the air extremely unpleasant. Under ordinary circumstances the carbon dioxide in badly vitiated places seldom arises above 50 parts per 10,000.

The measure of dilution necessary to keep air free from odors due to the presence of people is very easily understood, for we know that while fresh air contains about .03 per cent. of carbon dioxide, and air which has passed through the lungs about 4.41 per cent., the air of enclosed spaces becomes uncomfortably close and musty when the carbon dioxide exceeds .08 per cent.; this is about 5 parts per 10,000 above the amount in good outside air. It should be remembered that the odor does not depend on the amount of carbon dioxide; this gas has no odor and is only an indicator of respiratory impurity. The temperature and the amount moisture present contribute to an important extent in making the impure character of air apparent. The higher the temperature and the greater the humidity the more noticeable the odor becomes. An increase of humidity of 1 per cent. has as much influence on the sense of smell as a rise of 4.18 degrees of temperature.

The amount of carbon dioxide produced varies with different people according to their size and activity. In their studies of the ventilation of factories and workshops, the Committee of Parliament, already mentioned, considered that one cubic foot per hour was a probable average quantity produced by persons at work in factories.

According to Landois and Rosemann (Lehr. Physiol. des Men. Berlin, 1905, 11th Ed., p. 229), expired air contains a range of from 3.3 to 5.5 per cent. of carbon dioxide or an average of 4.38 per cent. by volume.

The observation of Atwater and Rosa (Bull. 63, U. S. Dept. Agri.) and Atwater and Benedict (Bull. 109, U. S. Dept. Agri., p. 142) give the most accurate estimation yet made in America of the heat given off by the breath and skin. The average of 13 experiments was 2,219 calories per 24 hours for an average man at rest, and, as an average of 6 experiments, 3,409 calories for a man at work. Since each calorie is equivalent to 3.968 B. T. U., 2,219 calories are equivalent to 8,804 B. T. U., or about two-thirds of the total heating value of one pound of good coal.

Among the most accurate determinations of the moisture produced by the breath are those of Atwater and Benedict. They found an average of 18.70 grams per hour per person at rest and 54.87 grams per hour per person at work.

At this rate every one hundred people at rest give to the air nearly half a gallon of water per hour. Billings (Princ. of Ventilation, N. Y., 1893, p. 135) gives as the smallest amount of cubic space permissible for common lodgings and tenement houses 300 cu. ft., and for school rooms 250 cu. ft., while for hospitals he suggested 1,000 to 14,000 cu. ft., depending on the requirements of the particular cases to be treated. Landois and Roseman give for dwelling rooms 795 cu. ft. and for rooms occupied by the sick 994 cu. ft. For school children in England the requirement is 80 cu. ft., with a floor space of 8 sq. ft. The standard for factories in England is 250 cu. ft. per person.

In the cars of the first New York Subway during rush hours, each passenger had about 2 sq. feet to stand on and an allowance of from 15 to 25 cu. ft. of space.

The number of cubic feet of fresh air per hour which most sanitarians consider necessary for ventilation per person is 3,000. The amount, however, must vary with circumstances. Billings advises from 1,800 for office rooms to 3,600 cu. ft. of fresh air per hour for hospitals.

Inadequate ventilation in mines and in tunnel construction reduces the working capacity of both laborers and foremen to an extent which is comparable only with the effects of malarial fever. As many experienced employers have found, much more work is done, the health of all is preserved and many indirect economies result in reduced cost when a working place is supplied with an ample volume of fresh air.

At first sight it would appear that the ventilation of city subway tunnels must be a part of a general problem which includes the ventilation of tunnels and mines, but this is not the fact.

The ventilation of mines is quite a different subject from the ventilation of subterranean roads in which trains are operated. Not only are the impurities to be dealt with different, but the movements of trains in subways and tunnels produce strong currents which would seriously interfere with the slow, regular movements of air which are desired in mine ventilation.

The ventilation of tunnels to be used by coal-burning locomotives is also a different problem from that of ventilating city subways operated by electric power. The ventilation of steam tunnels is in some respects a simpler problem.

It is the gases due to the combustion of fuel which cause the air to be vitiated in ordinary railway tunnels; it is the problems which arise from the assembling of large numbers of people which must be solved in managing the air of electrically-operated subways. In the one case we have to deal chiefly with poisonous gases, in the other chiefly with living agents of disease.

The correct management of the air of a subway requires a careful handling of many technical questions. The success of the work depends

upon the thoroughness with which the scientific elements of the problem are taken into consideration. In fact, in some modern tunnels, a highly skilful management of the air has been necessary to make construction and maintenance possible.

The difference between the conditions which surrounded the building of the St. Gothard tunnel, where 800 of the workmen died through defective hygienic arrangements and the Simplon, where, in the face of unprecedented obstacles, such a thing as vitiated air was unknown, and the hospitals empty, shows well what can be done when a serious effort is made in sanitation.

Air, like other ponderable substances, has certain physical properties which should be kept carefully in mind in even the most superficial consideration of questions of ventilation.

Air has weight and it is due to differences in the weight, caused chiefly by differences in temperature, that winds are formed and currents established which cause the atmosphere to circulate over the earth's surface, through city streets and even into houses and subways. One cubic foot of dry air weighs 536.29 grains, or 0.07661 lb., at the level of the sea and at 32 deg. Fahrenheit.

The weight of a given volume of air varies as its temperature, for it is the temperature which fixes its density. Air increases by 1/492 of its volume for every rise of 1 deg. Fahrenheit. Thus if the air of an enclosed space is 30 deg. warmer than the outside atmosphere, every pound of the latter will weigh about 1 oz. more than the same volume of air inside. It is for this reason that when cold air enters a room from an open window it sinks to the floor and does not mix freely unless it is deflected or agitated in some manner.

The flow of air through large, underground passages depends not only upon the frictional resistance offered by the walls of the passages. To force air through an airway by means of fans or otherwise often requires the overcoming of much frictional resistance.

The frictional resistance is proportional to the speed, to the perimeter and length of the airway and an arbitrary factor, which depends upon the form and roughness of the walls. The value of this constant, termed K, varies greatly, so that it is unsafe to assume any value for it without a close knowledge of the conditions to which it is to be applied. In mine ventilation K has been assumed to vary between 0.000000000158 for a straight, brick lined section to 0.000000001257 for a rough and crooked one.

Books have been written upon the calculations necessary to determine the best forms and materials with which to construct ventilating apparatus. It is unnecessary to enter into these details here, but a few of the formulae will show the way in which some of the more useful calculations are made.

The following formulae are for calculating the proper areas of passages, velocity of air, length of airways, quantities of air delivered, horse-power and pressure, etc.:

Let A=area of passage in square feet.

H=horse-power required for ventilation.

K=coefficient of friction due to movement of air through the airway.

L=length of airway.

O=circumference of airway.

P=loss in pressure in pounds per square foot.

Q=cubic feet of air.

S=square feet of surface producing friction.

U=units of work in foot pounds to move the air.

V=velocity of air in linear feet per second.

W=water gage in inches.

For the area of the cross-section of the duct necessary to accommodate a given flow of air:

$$(1)\quad A=\frac{K\,S\,V^2}{P}=\frac{K\,S\,V^2Q}{U}=\frac{K\,S\,V^3}{P\,V}=\frac{U}{P\,V}=\frac{Q}{V}$$

For the horse-power required to deliver the air:

$$(2)\quad H=\frac{U}{33000}=\frac{Q\,P}{33000}=\frac{5.2\,Q\,W}{33000}$$

To determine the frictional resistance offered by the walls of the duct to the flow of air:

$$(3)\quad K=\frac{P\,A}{S\,V^2}=\frac{U}{S\,V^3}=\frac{P}{S\,V\div A}=\frac{5.2\,W}{S\,V^2\div A}$$

For pressure in pounds per square foot:

$$(4)\quad P=\frac{K\,S\,V^2}{A}=\frac{U}{Q}=5.2\,W=\frac{K\,S\,V^3}{Q}=\frac{U}{A\,V}$$

For the quantity of air moved in cubic feet per minute:

$$(5)\quad Q=VA=\frac{U}{P}=\frac{K\,S\,V^3}{P}=\frac{\sqrt{P\,A}}{K\,S}\cdot A=\sqrt[3]{\frac{U}{K\,S}}\cdot A$$

To determine the units of work in foot pounds to deliver the air:

$$(6)\quad U=Q\,P=V\,P\,A=\frac{K\,S\,V^2Q}{A}=K\,S\,V^3=5.2\,Q\,W=33000\,H$$

To ascertain the velocity of the air in a duct:

$$(7)\quad V=\frac{U}{P\,A}=\frac{Q}{A}=\sqrt[3]{\frac{U}{K\,S}}=\sqrt[3]{\frac{Q\,P}{K\,S}}=\sqrt[2]{\frac{P\,A}{K\,S}}$$

To determine the water gage:

$$(8)\quad W=\frac{P}{5.2}=\frac{K\,S\,V^2}{5.2\,A}$$

The heating of the subways affects the comfort of the traveling public to such an extent that it may be well briefly to refer here to some of the physical principles which must be taken into account in disposing of the heat.

The warm air of a subway is due to the heat produced by the machinery and brakes on the trains. The heat generated from the bodies of the passengers is inconsiderable when compared with the amount which is due to the consumption of energy used in operating the trains. Were it not for the mechanical losses due to the production and transmission of the electric current, the heat produced in a subway would be the same as though the coal used up at the power house was consumed in fires along the track.

The only way for the heat to disappear is to escape through the walls or by the air. When subways are first put in operation much of the heat produced by the cars is transmitted through the metal and masonry linings to the earth surrounding them, but in course of time this earth becomes warm also, and little more heat can be absorbed. The subway air then grows warmer and unless some special means of removing the heat is provided, the air may become very uncomfortable. The most practical means of cooling a subway is to provide for a very large amount of ventilation.

The ways in which subways have been ventilated may conveniently be considered under four separate heads:

(1) By introducing or exhausting air at various points by means of fans.

(2) By forcing a current of air from one end to the other of the whole line by fans.

(3) By so-called natural ventilation.

(4) By the piston action of trains.

Fans are almost invariably employed to exhaust air, not to supply it. They may exhaust through side chambers directly to the outside air, as in older portions of the Boston subway, or by means of air ducts communicating at various points, as in the Severn and Mersey tunnels. In the former case a number of comparatively small ventilating fans are employed at the points where the air is to be extracted; in the latter, large central pumping plants are used. In any case, fresh air is expected to enter at stations or other appropriate points as rapidly as the foul air is exhausted.

In the plenum principle the fresh air is forced in by the fans and the foul air escapes as best it can. This method is more often used to supply air during construction of deep subways than in subways after they are built. Many arguments have been brought forward to show the advantages of renewing the air at stations rather than elsewhere.

It has been urged, for example, that the air should be exhausted between stations and allowed to flow in at the stations since (a) more passengers are congregated at stations than at other points and in this way they will get the freshest air; (b) the air in the cars is renewed

at stations and not between them, so the air should be at its best there; (c) this method would most rapidly remove smoke and heat in case of fire and give the best opportunity for escape through the stations.

The earliest use of a fan for assisting the ventilation of a railway tunnel is believed to have been in 1870 in connection with the Lime Street tunnel of the London and Northwestern Railway at Liverpool. Following the generous proportions of fans which had been employed in ventilating mines, this fan was 29½ feet in diameter and discharged its air into a conical brick chimney 54 feet in diameter at the base. The quantity of air thrown was 431,000 cubic feet per minute. The air was taken from a point midway between the two ends of the tunnel. The tunnel was 6,075 feet in length. (Francis Fox, Trans. Am. Soc. C. E., Vol. 54, Part C, p. 554.)

The Boston Subway is about 4⅓ miles long (1908) and is operated by electricity. It is used by trains and single trolley cars, most of whose routes lie in the open air. The speed is so slow that the ventilating currents set up by the moving cars are often scarcely noticeable. The typical section is 332 square feet where the subway is occupied by two tracks and 707 square feet where it is four tracks wide.

In the section of the road first built ventilating fans are placed in chambers alongside of the subway at points between stations and the air is discharged upwards through grated openings in the sidewalk overhead or through short shafts to the other air. The fans are 7 to 8 feet in diameter. They were intended to be of such capacity as to enable them to completely renew the air every ten minutes.

In the section under the harbor the same general plan is followed of taking air in at the stations and removing it between stations. In this case, however, an exhaust duct has been placed along the top of the tunnel with occasional openings which can be opened or closed at pleasure. The cross-section of the duct is about 48 sq. ft.; the openings are about 4 ft. long and 1 ft. 5 in. wide and they are placed at intervals of about 550 ft.

The air is withdrawn at each end of the tunnel and exhausted by means of fans through shafts about one mile apart, on the opposite shores. At the East Boston end the air is exhausted through grated openings in the sidewalk 40 ft. long and 7 ft. 1 in. wide. At the other end the air is discharged about 21 ft. above the surface of the street.

The fans consist of two 8-ft. vertical fans at the East Boston end and two 7-ft. horizontal fans at the Atlantic Avenue shaft. At 175 to 218 revolutions per minute and about 12 horse-power each, the total rated capacity of the whole ventilating plant is 90,000 cu. ft. per minute. This gives a theoretical velocity for the whole air in the tunnel of about 2½ ft. per second and is equivalent to a renewal of the air every 15 minutes.

A complete description of the ventilation arrangements of the Boston Subway has been given by H. A. Carson, Chief Engineer of the Boston Transit Commission in the Proceedings of the American Society of Mechanical Engineers, Vol. 28, pp. 927-942.

The Severn tunnel of the Great Western Railway was opened in 1886. It is about 4⅜ miles long. It is occupied by two tracks for steam railway travel. There is a ventilating shaft located near the center, through which air is exhausted by means of a fan 40 ft. in diameter. It is said that the capacity of the fan is sufficient to renew the air of the tunnel about every ten minutes.

The Mersey tunnel, connecting the cities of Liverpool and Birkenhead, is about two miles long and is occupied by a double line of electric railway. Air is exhausted through numerous passages communicating with ventilating galleries which lead to exhaust fans. These fans are from 12 to 40 ft. in diameter and are located at stations above ground. The combined capacity of these fans is estimated to be about 950,000 cubic feet per minute or sufficient to renew the air of the tunnel every nine minutes. This tunnel is often referred to as affording an example of the most perfect system of artificial ventilation yet devised. It was certainly the earliest tunnel in which a comprehensive system was adopted.

The general plan of ventilating the new tubes of the Electric Underground Railways Company of London is to take advantage of the piston action of the trains, as do all the London subways, and to supplement this by fans at the stations.

The fans exhaust air from beneath the station platforms and carry it through airways averaging 12 to 16 ft. in cross-section to the roofs of the buildings used for subway stations, there to be discharged into the free atmosphere. The fresh air enters through these stations, stairways and lifts.

The fans are of a designed capacity sufficient to remove 1,000,000 cubic feet of air per hour when working at moderate speed. This is sufficient to renew all the air in the average length of subway between two stations in each of the parallel tunnels every thirty minutes. The fans are located at the tops of the buildings. They have been found, upon test, to deliver 18,250 cu. ft. per minute when operated at a velocity of 242 revolutions per minute. Great care was used to avoid vibration and noise from the motors and fans.

A system of forcing air through an electric subway has been installed in connection with the Central London Underground, a good example of the deep London tubes.

The ventilating arrangement of the Central London Railway is capable of renewing all the air contained in this subway three times over every night. In order to accomplish this result double doors are arranged at the station entrances and shut at night. The air flows in at the city end of the Bank of England, passes through the two tubes, each over six miles long, and is exhausted by a fan at Shepherd's Bush.

The fan is 20 feet in diameter, of the Guibal type. It is said to be capable of exhausting 100,000 cu. ft. of air a minute as measured at a point near the far end of the line. During the day it is not possible to run this far with much effect, because, with opening the station

doors by passengers, it draws air from the stations, chiefly from the nearest one. But at night after the last train has run out of the subway on the surface at the west end all the doors are closed and the fan is started. It is kept going until the first train is run in the morning. The results are said to be excellent.

Although many subways are now provided with some system of ventilation requiring the use of fans, by far the greatest number still depend for a circulation of air upon currents set up without special mechanical aid.

Among the more common ways of securing the so-called natural ventilation, the use of blowholes, or free openings to the outside air, deserve special notice. It is to ventilation accomplished in this way that the frequent renewal of air in the New York Subway is due.

The draught of air passing through the blowholes is sometimes violent. An average velocity of 16½ miles per hour through the stairways of the New York Subway was observed as a result of several hours' observation with anemometers. Had this current taken place through one-half of the openings between Ninety-sixth street and the Brooklyn Bridge, the quantity of air so supplied would have been capable of renewing the entire atmosphere of the subway every few minutes. At first sight it would appear that nothing could be easier than to ventilate a subway by this means. It seems as simple as opening the window of a living room. Yet to get the best effects from blowholes, ventilation means much more than the opening of the roof. To provide for a suitable and reliable movement of air requires careful study. Apparently the very simplicity of the idea of blowhole ventilation has prevented the development of this principle in the best manner. To some subways and tunnels it is peculiarly suited. The term blowhole is here used to include all openings through which the confined air can escape and fresh air enter, whether they be stairways, openings in the roof or openings through side chambers. In shallow subways such openings usually pierce the roof or lead from station platforms with more or less directness to the outside air. They are usually much too small, too indirect and too long to accomplish all the benefit which may be obtained from them.

Inasmuch as the flow of the air is impeded by friction against the walls, blowholes should be as short as practicable. Since the friction increases as the square of the velocity of the current and inversely as the diameter of the passage, they should be large in section and but little obstructed by screen, doorways, nettings and other incumbrances.

It is easy to see that blowholes may be more advantageously employed in subways built near the surface of the ground than in railways far beneath the surface. And yet this is the only way in which some of the deep London tubes are ventilated. If, as sometimes happens, the blowholes are open stairways covered by cowl-like kiosks, the direction of the openings with respect to prevailing breezes may materially aid or interfere

with the amount of air which passes in or out. Let us briefly examine this effect.

A breeze which is just perceptible may be assumed to travel at a velocity of 2.92 ft. per second and to exert a pressure of 0.02 lb. per square foot and a breeze of twice this velocity exercises four times this pressure. A brisk wind traveling at a velocity of 25 miles per hour or 36 ft. per second, a not uncommon occurrence in New York at some seasons of the year, exercises a pressure of about 3 lbs. per square foot. A wind of 45 miles exercises a pressure of 10 lbs. If a pleasant breeze of 2½ miles per hour acts full upon a kiosk measuring 5½x7½ ft. it is as effective as two fans, each 6 ft. in diameter, turning at the rate of 200 revolutions per minute and delivering 21,200 cu. ft. of air per minute.

The action of moving trains is more important than any other factor in establishing a circulation of air through blowholes. This so-called piston or plunger action has long been recognized as useful, but it has remained for the New York Subway to demonstrate how extremely beneficial it may be. The main principle of the phenomenon of piston action is easily understood. The moving trains force air ahead of them and cause air to rush in after they are passed. The quantity of air moved depends upon many circumstances. Chief of these are (a) the extent to which the tunnel section is filled by the section of the train; (b) the speed of the train; (c) the opportunity afforded by blowholes for the air to flow in and out; (d) the shape of the forward end of the train.

In studies made on the Berlin-Zossen Railway into the resistence offered by the free outside atmosphere to the movement of trains, it was found that air piled up in front of the first car in the form of a cone of increased pressure and that a cone of reduced pressure followed behind the train. For example, the pressure in front of a car (which presented a face perpendicular to the line of the track) was 4.09 lbs. per square foot at a speed of 12.4 miles per hour; 6.14 lbs. at 18.6 miles; 8.19 lbs. at 24.8 miles. This pressure was maintained for between 10 and 16 ft. in front of the moving train; beyond this it gradually fell off (Street Railway Journal, New York, October 28, 1905, p. 802).

Observations made in the New York Subway before any material changes were made in the arrangements for ventilation, with the ordinary train service of early afternoon, have shown that air passed from one station to another sometimes at a rate of over 8 miles per hour and at an average of about 3 miles. The approach of a train toward a station on the four-track road could be felt by the flow of air ahead of it while the train was over 1,000 ft. away.

The exhaling and inhaling action due to the operation of trains is of peculiar value in that it occurs when and where most needed, provided, of course, that the openings to the outside air are properly placed and unencumbered. The greater the number of passengers carried

and the greater the number of trains, the greater is the amount of ventilation. And not the least conspicuous of the advantages of so-called natural ventilation is its economy.

No expense is necessary for the operation of mechanical devices in natural ventilation. Experience with the New York Subway shows that it is not always necessary or desirable for a train to fit very closely into the tunnel section. In fact it is conceivable that when this fit is close, the cars carry along more of their own air than desirable and the passengers within them enjoy much less interchange than would take place otherwise.

The details of construction and equipment of the New York Subway have been made the subject of so many extended and authoritative accounts that it is unnecessary to deal exhaustively with these questions here.

The subway structure may briefly be described as virtually a steel cage enclosed and embedded in concrete. The walls and roof were alike in design, consisting of beams weighing from 42 to 70 lbs. per foot, placed about 5 ft. apart. Between these beams square, steel rods 1¼ in. long were placed to the extent of from 4 to 7 per 5-ft panel. Round rods ⅝ in. diameter connected the columns about 2 ft. below the under face of the roof. The rods were set back from the inner face of the tunnel 2 in., but the beams projected to the surface.

Between the beams of the roof and sides comparatively thin walls of concrete imbedded the steel cage. This concrete has a thickness at the walls of from 14 to 16 in., exclusive of a thin protective wall of waterproofing outside, and of a space of variable thickness occupied by hollow ducts intended to contain electric cables. The roof has a thickness which varies from 18½ to 21½ in. In the four-track section of the subway rows of steel columns extend between each two lines of track at intervals of 5 ft. to support the roof. The floor is of concrete with an enclosed layer of waterproofing.

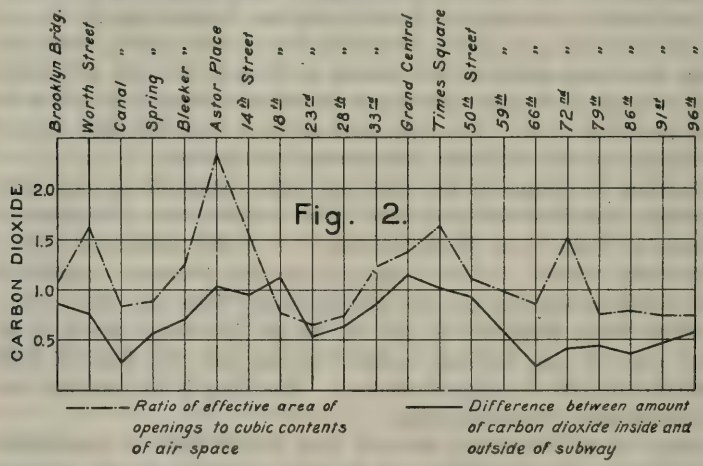
Nearly all of the studies recorded here, except those of temperature and humidity, refer especially to the representative section between Ninety-sixth street and Brooklyn Bridge. In many cases they have a much wider application.

The length of this section was about 6 miles. The cubic air space included was in round figures 26,100,000 cu. ft., including the stations.

The section was 4 tracks wide, excepting a piece of tunnel which ran between Forty-second and Thirty-fourth streets. Here there were two tunnels of two tracks each, running side by side cut through the rock. The subway was ventilated through the stairways at the stations and through blowholes in the roof. All of the blowholes which were originally built were located in that portion of the road which lay above Sixtieth street. They were rectangular in shape, and opened upon small grass plots which occupied the center of a wide boulevard known as Upper Broadway. Iron railings surrounded the openings. To prevent

the entrance of large objects the openings were covered with coarse wire netting.

The blowholes were located above the center of the railway, one being situated a little beyond each end of each station. An additional blowhole was placed midway between stations. The total number of blowholes between Fifty-ninth and Ninety-sixth streets was eighteen. Each was about 7x14½ ft. in the clear. Wire nettings, beams and other objects took up about one-quarter or more of their space so that the total effective area from these blowholes was about 1,368 sq. ft. Sections of the vault lights were early removed from the stations at Seventy-second and Ninety-sixth street and left unobstructed by nettings. The area removed at Seventy-second street was about 108 sq. ft. and at Ninety-sixth street about 478 sq. ft. This greatly relieved the unsatisfactory condition of the air at Seventy-second Street where the subentrances had been covered by a building, and at Ninety-sixth street



where the roof was very low and the extent of the vault lights extraordinarily great.

The stairways between the streets and the stations varied somewhat as to width and direction. Below Fifty-ninth street they were usually placed at right angles to the line of the road; above Fifty-ninth street they were parallel to the road. There were usually two stairways, each in cross-section about 5½x7½ ft., to each local station above Fifty-ninth street and eight narrower ones to the other local stations.

The stairways were covered with ornamental kiosks which stood upon the sidewalks near the curbs. They were without doors. The kiosks opened north and south above Fifty-ninth street; below Fifty-ninth street they usually faced east and west.

The subway was about 59 ft. wide and 18 ft. high on the four-track section between Brooklyn Bridge and Ninety-sixth Street and the cross-

section of a car occupied about 14 per cent. of this section. The trains were from about 150 ft. to 408 ft. long.

The local trains usually consisted of five cars and ran at a rate, exclusive of stops, of about 21 miles per hour. The express trains generally consisted of eight cars and ran at a rate, exclusive of stops, of about 26 miles per hour.

As a train moved through the subway air was forced ahead of it and air followed it. As a rule, a general current flowed along the track on each side of the subway in the direction of the train movement, and these currents continued even when no train was within hearing distance. The important action of a train was to force air along with it, but where stairways or blowholes occurred and offered lines of diminished resistance, the air rushed out through them as a train approached and rushed in as the train went by.

The difference in barometric pressure necessary to set up these air currents was exceedingly slight; the effects of friction against the walls and pillars of the subway and the sides of the stairways considerable. A great part of the force with which the air currents were set in motion was generally used up in eddies about the trains.

The movement of the air depended upon the speed of the nearest train, the movement of other trains in the vicinity, the size and location of the neighboring openings to the outside air, the size of the particular cross-section of the subway with reference to the sections of the moving trains, the force and direction of the wind in the streets with reference to the position of the stairways, the difference in temperature inside and outside of the subway and other conditions.

From approximate computations made in a number of ways, it is practically certain that the air was renewed at least as often as once every half hour.

Observations with anemometers were made at a number of stations on several occasions. As a result it was calculated that an average of 573,000 cu. ft. of air moved in and out of one stairway per hour. This was at the rate of 9,550 cu. ft. per minute. The maximum movement of air observed was when 63,000 cu. ft. passed in at one station in one minute through a single stairway. The velocity of the current on this occasion was 16⅓ miles per hour.

With the object of reducing the heat which had made the air uncomfortably warm during the summer months extensive alterations were made in ventilating arrangements of the New York Subway after the above observations were made. The plan embodied several features.

Large sections of the roof were removed at the stations and the openings were covered with gratings. The aggregate area of the opening when allowance was made for the gratings, was 2,356 sq. ft. in the section from the Brooklyn Bridge to Columbus Circle, and 1,805 sq. ft. in the section between the latter point and Ninety-sixth street. It was calculated that these openings, together with the openings at the station

stairways, etc., would give a ratio of 1 sq. ft. of blowholes for every 3,200 cu. ft. of contents at each station.

Blowholes, opening generally from specially constructed chambers, were also provided between stations. These blowholes were fitted with air valves and fans, the object of the arrangement being to induce fresh air to enter at the stations, and pass out through the blowholes between stations.

The air valves, called louvres, were made of galvanized iron and were so fitted into sheet iron boxes that when shut they entirely closed the area of the blowholes in which they were placed. The valves swung automatically upon axles, being so counterweighted as to open and let air out when it was forced ahead by the trains and then close and prevent fresh air from getting in after the trains had passed. The ventilation with the valves was like the natural ventilation which would have taken place without them, in one respect; they were entirely dependent upon the movements of the trains, producing an amount of ventilation which was proportioned to the number of trains passing in a given period.

These louvres were fully described in the report of George S. Rice, Chief Engineer, in his report to the Rapid Transit Railroad Commission for 1906. He states that a discharge of 19,000 cu. ft. of air has been observed to take place through 100 sq. ft. of louvres between 6 a. m. and 8 p. m., an average of 14,400 cu. ft. between 8 p. m. and 1 a. m. and 4,800 cu. ft. between 1 a. m. and 6 p. m, under conditions of average working.

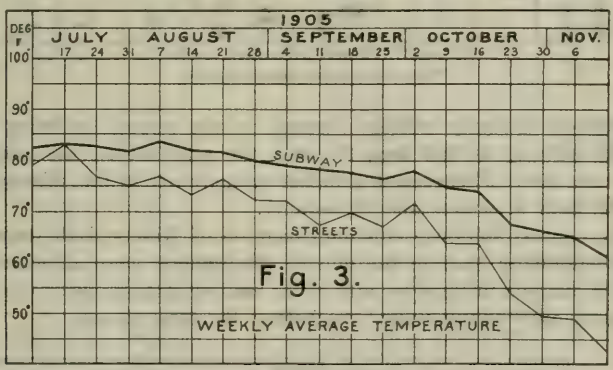
The louvre openings between Brooklyn Bridge and Columbus Circle (Fifty-ninth street) were estimated by Mr. Rice to have a capacity of passing 675,000 cu. ft. of air per minute which, being replaced by fresh air coming in through the stations, is equivalent to a renewal of all the air of this section about once in 27 minutes. Similarly the valves between Columbus Circle and Ninety-sixth street were considered to be capable of renewing the air in this section about once in 33 minutes.

The fans have been placed at the ventilating openings between stations to accelerate ventilation under special circumstances, such, for example, as at night when few trains are running and in order to free the subway of smoke in case of fire. The fans are of the centrifugal type popularly known as blowers. They are from 5 to 7 ft. in diameter. They are operated by electric motors of 15 to 30 horse-power capacity and when run at their normal speed of 235 to 330 revolutions per minute are said to be capable of discharging about 990,000 cu. ft. of air per minute. On the basis that the fans are really capable of operating as effectively as assumed, they should be able to renew the air between Columbus Circle and Brooklyn Bridge in 19 minutes.

A plant for cooling the air at the Brooklyn Bridge station was constructed in 1906. The project required that the heated air of this station should be passed by means of a centrifugal fan over coils of

cold water and distributed through ducts opening immediately over the heads of the passengers at the station. The plant was designed by John E. Starr and is fully described in the report of Chief Engineer Rice above referred to.

The water for the cooling plant is obtained from an artesian well from which it is pumped at the rate of about 200 gallons per minute. The quantity of air cooled is about 75,000 cu. ft. per minute for each of the two units into which the plant is divided. The cooling arrangement at the Brooklyn Bridge was put in operation August 29, 1906, and has been run intermittently during the hot weather. When first put in operation, it was found that there was a transfer of heat between 9.4 and 11.3 B. T. U. per square foot per degree of difference between the air and the water and that the air which came in contact with the pipes could be cooled about 8 deg. under the conditions of practical operation.



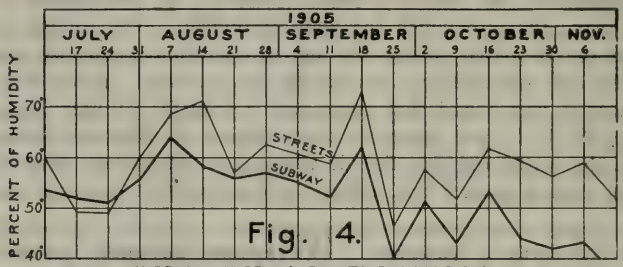
Result of 47476 observations

In view of the overheating of the subway, which has been a characteristic of the road since 1905, it is interesting to review some of the temperature characteristics of the road before it was thrown open to travel. The entrances, exits and blowholes being more or less closed.

Before trains were run, hourly and daily changes of temperature in the streets seemed to affect the subway but little. The more marked and continued changes, however, produced visible effects.

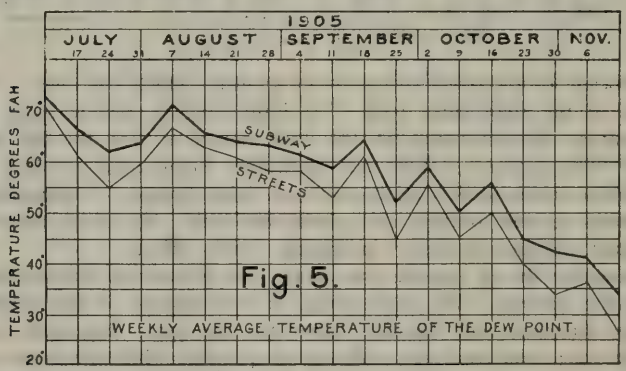
In winter the air outside was cooler, and in summer warmer than the air in the subway. The total range of temperature of the subway air at One Hundred and Twelfth street for the year, August 6, 1903, to July 27, 1904, was from 22 to 68 deg. or 46 deg.; while the range outside was from 2 to 94 deg. or 92 deg. The range in the street being twice as great as the range in the subway. During the hottest week in the subway, before it was opened, the temperature, according to the One Hundred and Twelfth street records, averaged 59.4 deg., while the street temperature was 77.7 deg. At its hottest the subway was 18.3 deg. cooler than the streets.

From the middle of August until the opening day, October 27, 1904, the subway was gradually cooling and the temperature continued to fall until the end of the year. For the first ten weeks in 1905 the subway was slightly warmer than in 1904. Beginning about the middle of March, or at that season when in other years the temperature inside and outside had been about the same, the heating due to the operation of the road



first became distinctly visible. Instead of the streets becoming warmer than the subway as had been the case the year before, the temperature inside rose also. Thenceforth a higher temperature in the subway became the rule, both in winter and in summer.

The express stations, with the exception of Ninety-sixth street, which was exceptionally open to the outside atmosphere, were all warmer than the local stations in their vicinity. The coolest stations were those which were most open to the street; the hottest the most closed.



The relative humidity in the subway was generally less than that out of doors, but the temperature of the dew point was higher.

The humidity of the subway varied with the humidity out of doors.

The average relative humidity for the subway for July and August was 57.5 per cent.; for the outside air 60.6 per cent.

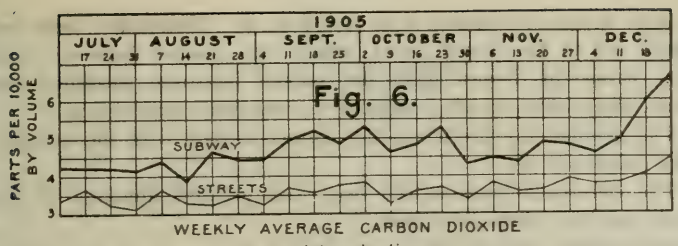


Fig. 6.

WEEKLY AVERAGE CARBON DIOXIDE

4772 determinations.

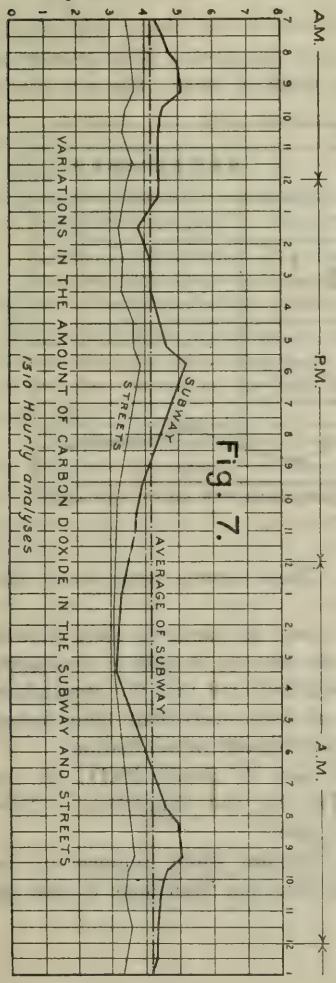


Fig. 7.

The average amount of carbon dioxide in the subway was a little larger than the amount in the air of the streets.

The average of all results was, for the subway 4.81 volumes per 10,000 volumes of air, and for the streets 3.67. A very slight difference.

The carbon dioxide in the subway varied according to season, hour, place where samples were collected, and other circumstances.

There was more in autumn than in summer or winter.

The amount of carbon dioxide varied in the subways at different hours of the day (see Fig. 1). There irregularities correspond with the irregularities in the amount of travel which took place at different hours.

It is interesting to note that periodic changes in the amount of carbon dioxide occurred in the streets, being highest between 5:30 and 6 p. m, and lowest between 1 and 3 a. m. The amount increased from a minimum in the early morning hours to about 9 a. m. After this there was a fall to about 1:30 p. m., followed by a rise to the highest point of the day, which occurred between 5:30 and 6 p. m. The average range of CO outside, as determined by hourly results, was .8 per 10,000.

In the subway the greatest amount of carbon dioxide for the whole

day also occurred between 5:30 and 6 p. m. Thereafter there was a gradual fall to the lowest point, which was reached between 3 and 4 a. m. From this lowest point the amount increased steadily to about 9 a. m., after which it fell irregularly to between 1 and 2 p. m.

The average for the whole day agreed closely with the average between 1 and 3 p. m.

The difference between the least and greatest amounts of carbon dioxide was two parts per 10,000.

The average amount of oxygen found in the air of the street was 20.71 per cent.; in the subway 20.60 per cent. The lowest amount found in the subway was 20.25 per cent.

The numbers of bacteria found in the dust of the subway were smaller than the numbers found in the dust from the street. This average of dust from the subway was 500,000 per gram of dust. The average of

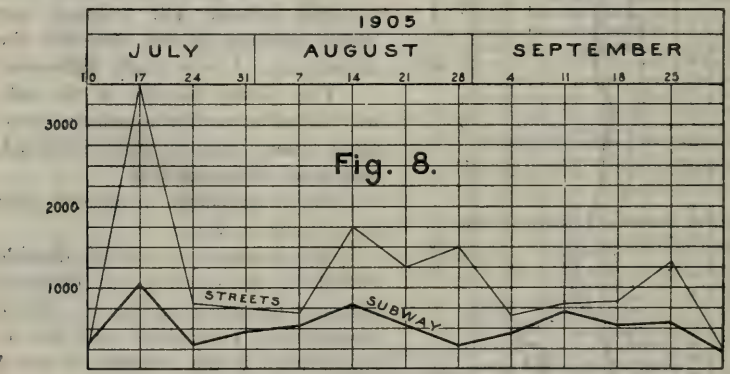


Fig. 8.

subway air was 3,200 per cubic meter. These figures were about one-half of those found in the street.

The investigation made from July, 1905, to January, 1906, showed that the chemical condition of the air of the subway, in spite of unpleasant odors and heat, was remarkably good, and indicated that the atmosphere of the subway was completely renewed at least every half hour before any material change had been made in the methods of ventilation.

Your Committee is indebted to Dr. Geo. A. Soper, Ph.D., for the foregoing information abstracted from The Air and Ventilation of Subways. (John Wiley & Sons, New York, 1908.)

The following statement by Geo. H. Pegram, Chief Engineer of the Interboro Rapid Transit Company, shows what has been done to date on ventilating the subway.

VENTILATION IN THE SUBWAY.

NORTH OF FULTON STREET.

In the original construction ventilating openings were provided in the roof of the subway on its middle line about every two blocks from north of Sixtieth Street to north of One Hundred and Fifteenth Street on Broadway. Subsequently these openings, extending as far as that opening between Ninety-sixth and Ninety-seventh Streets were equipped with moving louvres. These louvres are constructed of galvanized sheet iron and designed so that the movement of air ahead of an approaching train will keep them open and with the suction after the train has passed the louvres will close, thereby preventing the return of the previously expelled air.

Shortly after the opening of the subway, holes were cut in the vault light construction at the Brooklyn Bridge Station and the Ninety-sixth Street Station. In 1906 similar openings were cut at all stations from Brooklyn Bridge to Ninety-sixth Street, inclusive, and provided with gratings on the sidewalk plane. About the same time ventilating chambers were constructed alongside the subway, beginning south of Brooklyn Bridge and ending at Fifty-fifth Street, one chamber occurring between stations throughout this district, with the exception of the section of the road occurring between Thirty-third Street and Grand Central Station. These chambers generally extended under the sidewalk and were covered with a grating on sidewalk surface. The side wall of the subway was cut out between the steel column and moving galvanized iron louvres, acting in the same manner as those described above, were constructed.

In each of these chambers is located one or two large fans, which are operated throughout the summer months from 7 p. m. to 7 a. m., excepting when the temperature is 82 degrees and over, when they are operated throughout the 24 hours. The operation of the louvres permits the expelling of air at these points and results in the intake occurring at a station through the stairway opening and the openings in the vault light construction previously described.

Below is given a list of the locations of these chambers and the capacity of their fans:

West side of subway in sidewalk of City Hall Park:
2 5′ Fans: capacity 21,000 cu. ft. per minute.
West side of subway near Duane Street:
1 7′ Fan; capacity 40,500 cu. ft. per minute.
East side of subway at Franklin Street:
1 6′ Fan; capacity 30,500 cu. ft. per minute.
East side of subway at Grand Street:
1 7′ Fan; capacity 40,500 cu. ft. per minute.
East side of subway at Prince Street:
2 6′ Fans; capacity 30,500 cu. ft. per minute.
East side of subway at Fourth Street:
2 6′ Fans; capacity 30,500 cu. ft. per minute.

East side of subway at Eleventh Street:
2 6′ Fans; capacity 30,500 cu. ft. per minute.
West side of subway at Sixteenth Street, in Union Square Park sidewalk:
2 5′ Fans; capacity 21,000 cu. ft. per minute.
East side of subway at Twenty-first Street:
2 5′ Fans; capacity 21,000 cu. ft. per minute.
East side of subway at Twenty-fifth Street:
2 5′ Fans; capacity 21,000 cu. ft. per minute.
West side of subway at Thirty-first Street:
2 6′ Fans; capacity 30,500 cu. ft. per minute.
South side of subway at Bryant Park:
2 7′ Fans; capacity 40,500 cu. ft. per minute.
East side of subway at Forty-sixth Street:
2 6′ Fans; capacity 30,500 cu. ft. per minute.
West side of subway at Fifty-fifth Street:
2 7′ Fans; capacity 50,500 cu. ft. per minute.

In 1907 openings were cut in the vault light construction at One Hundred and Third, One Hundred and Tenth, One Hundred and Sixteenth, One Hundred and Forty-fifth and One Hundred and Fifty-seventh Street stations, Broadway, and gratings provided as at other stations. At the same time a series of openings were constructed along the middle of structure over the One Hundred and Thirty-seventh Street-Broadway Yard; these openings extended from north of One Hundred and Thirty-ninth Street to south of One Hundred and Forty-third Street, being located in parklets and provided with gratings same as others.

In the Central Park Tunnel inside of Central Park line on easterly side of Fifth Avenue there is a ventilating shaft with head house in park; no apparatus.

SOUTH OF FULTON STREET, AND BROOKLYN EXTENSION TO ATLANTIC AVENUE.

In original construction ventilating openings in vault light construction were provided in passageway under the easterly Broadway sidewalk, provided with gratings as similar openings. In Battery Park, opposite Bridge Street, over the approach to the East River tunnel, a large ventilating opening extending over both tracks. In Battery Park, near South Ferry, ventilating shaft extending from the park surface down to the tunnel tracks, and near Willow Place, Brooklyn, a similar shaft. These shafts are provided with blowers, capacity 46,000 cu. ft. per minute, with ducts leading down into the tubes to be used on special occasion as may be required. At all the stations in Brooklyn there are ventilating openings with gratings in sidewalk similar to those constructed in Manhattan Borough.

On the north side of the subway at Fulton Street and DeKalb Avenue and on the east side at Flatbush and Lafayette Avenues, are ventilating chambers covered on street surface with gratings, the side wall of subway being left open. No louvres or other apparatus.

At the Brooklyn Bridge Station a cooling plant was installed in 1906. This plant consists of four pipe-driven wells driven down through the

floor of subway at north end of platforms from which two motor driven triplex pumps of 175 gals. per minute capacity draw water and pump it through pipe coils. Two motor driven fans, 9 ft. diameter, 35,000 cu. ft. per minute capacity, propel air through these pipe coils and through iron ducts over the express platforms of station. In these ducts are frequent openings from which the air is expelled over the said platforms. This is operated when the temperature is 80 deg. and over.

The continual increase in the amount of traffic and the variable conditions of the weather have rather discouraged any attempts at determining the effects of ventilation which has been provided.

VENTILATION OF THE HUDSON RIVER TUNNELS.

The tunnel system of the Hudson & Manhattan Railroad Company has been in operation about five years between Hoboken, N. J., and Sixth avenue, New York, and the downtown section between Hoboken and Church street, New York, about four years. Those sections now in operation extend from the Terminal Building, at the lower end of New York, under the Hudson River to Jersey City, thence underground to the Erie and Lackawanna railroad stations whence they pass under the river again back to Manhattan at a point about 1¼ miles above the downtown tubes. Continuing below ground the tunnels extend to Sixth avenue and thence to Thirty-third street. In Jersey City the line to Newark comes to the surface about 1½ miles west of the Pennsylvania Railroad Station. Extensions now under way will carry the tunnels further up Sixth avenue and eventually to the Grand Central Station at Forty-second street and Fourth avenue.

The total length of the tunnels when completed will be 19 miles. The approximate distance between different stations is as follows:

Church Street Terminal to Pennsylvania Station	1¼ miles.
Pennsylvania Station to portal on Newark Line	1½ "
Pennsylvania Station to Erie Station	1 "
Erie Station to Hoboken Station	4/5 "
Hoboken Station to Christopher Street Station	2 "
Christopher Street Station to Twenty-third Street Station	1⅛ "
Twenty-third Street Station to Forty-second Street	1½ "

The Hudson tunnels were designed by Charles M. Jacobs, the Chief Engineer of the Hudson Companies. They are single track tubes, there being no connection between adjacent tubes except at junctions and at some stations. This plan has been adopted throughout, and it is of great importance in the ventilation, as only by this means can full advantages be taken of the piston action of the trains to maintain efficient circulation of the air. The Fourteenth, Nineteenth and Twenty-third street stations are constructed on the same principle, but structural and operating requirements would not permit the scheme at other stations.

The effective area of the iron-lined tunnel is 160 sq. ft. and of the concrete-lined tunnel 166 sq. ft. This is with ballast and bench wall in place.

The cross-section of the standard tunnel car is approximately 90 sq. ft., which leaves a clearance area of 70 sq. ft. and 76 sq. ft. respectively, for the iron and concrete tunnels.

The original layout of the ventilating system was made by A. C. Powers, then ventilating engineer with the Hudson Companies, and was designed to take full advantage of the piston action of the trains and to draw out the foul air with exhaust fans, while using entrances to admit fresh air. But in three cases it was considered necessary to install fresh air blowers to supplement the air delivered through the entrances, which were either too small or too far apart for this purpose, and also to create sufficient circulation should trains become stalled in the tunnels.

The capacity of the fans was designed to give 30 cu. ft. of air per passenger per minute when traffic is at the maximum during morning and evening rush hours, and this capacity would change the air in the tunnels approximately 2½ times every hour.

All fans are motor driven, the motors being coupled direct to the fan shaft. The motors are specially built of the inter-pole type, designed to operate under large voltage fluctuations. They are extremely rugged, reliability being of extreme importance in the installation. The speed variations in these motors is 20 per cent. All speed changes are obtained economically by field control. The motors are designed to operate on a 625 volt circuit which has fluctuations between 500 and 750 volts.

The specifications and plans for the electrical equipment were made by R. B. Stilwell and W. Hazelton, consulting electrical engineers for the Hudson & Manhattan Railroad Company.

Following is a list of the ventilating equipment installed up to date:

DESCRIPTION OF APPARATUS INSTALLED.

Size of Fan, inches	Diam. wheel, inches	Cap. in cu. ft. air per minute	H. P. of motors	R. P. M.	Type.	Location.
160	96	57,000	45	250	Exhaust,	Church St. Terminal
160	96	57,000	45	250	Exhaust,	Church St. Terminal
80	48	15,000	75	1,150	Plenum,	Church St. Terminal
80	48	15,000	75	1,150	Plenum,	Church St. Terminal
90	60	18,000	13	345	Plenum,	Hoboken Terminal
90	60	18,000	13	345	Plenum,	Hoboken Terminal
120	84	32,250	40	300	Exhaust,	Hoboken Terminal
120	84	32,250	40	300	Exhaust,	Hoboken Terminal
90	96	.....	30	230	Cone,	Fifteenth St. Shaft
90	96	.....	30	230	Cone,	Fifteenth St. Shaft
90	60	33,000	50	545	Plenum,	Christopher St. Station
90	60	33,000	50	545	Plenum,	Christopher St. Station
160	108	62,000	55	215	Exhaust,	Morton St. Shaft
160	108	62,000	55	215	Exhaust,	Morton St. Shaft

The fans are of the American Blower Company and Massachusetts Fan Company make.

In November, 1909, A. W. Hodgson, Assistant Engineer of the Hudson & Manhattan Railroad, made a series of anemometer tests to ascertain the direction and volume of air circulating through the tunnels and station passageways under existing circumstances. (See Heating and Ventilating Magazine, N. Y., May, 1910.)

All readings were taken with trains running on 2½ minutes headway, except in the tunnels between Caissons 1, 2 and 3, where the headway was 5 minutes. The temperature on the street was close to the freezing point or below.

The average velocity of the air from the downtown river tunnels was 1,100 ft. per minute with trains on 2½ minutes headway. The highest recorded temperature in the tunnels was 76½ degrees in August, 1909, when the temperature on the street was 88 deg. Many other parts of the tunnel were only 70 deg. on this date. The average temperature of the tunnel is generally 70 deg. The train headway during rush hours is 1½ minutes with four and five car trains.

With trains on 2½ minute headway the velocity and direction of the air is governed almost entirely by train movements and not by fans. The large exhaust fans at Church Street Terminal, handling 114,000 cu. ft. of air per minute, increase the velocity in the river section of the south or inbound tunnel less than 10 per cent. over the velocity in the north or outbound tunnel.

The velocity in the river section of the outbound tunnel was influenced largely by the number of doors and ventilators open at Church Street Terminal entrances, being 180,000 cu. ft. on December 13, and falling to 126,000 cu. ft. per minute on December 23, when all doors and ventilation were closed.

It is, therefore, evident that the function of the fans is only to take the air pushed to them by the trains or to deliver fresh air where the trains can push or draw it in through the stations and tunnels, and this fact should mainly govern the location of fans and air ducts.

In the river sections of the iron-lined tunnels, with trains on 2½ minute headway and attaining an average speed of 30 miles per hour, the mean volume of air passing at any point is 180,000 cu. ft. per minute provided that the air is not restricted by closing all possible inlets.

At island platforms, such as Christopher and Erie stations, also crossovers, such as Ninth street and Nineteenth street, about 70 per cent. of the air crosses the platforms or tracks within 50 feet from the end at which it enters and follows the direction of traffic in the adjacent tunnel. The 30 per cent. leaves the station in the same tunnel in which it enters.

The results prove that wherever passages or connections of considerable area are made between two adjacent tunnels, the section of tunnel between any two such connections must be considered independently, and cannot be efficiently ventilated by fans or shafts not within that section.

The tunnels between the Church Street Terminal, Erie and Newark Avenue Stations depend almost entirely for fresh air on the entrances at the Church Street Terminal.

The exhaust fans at the Church Street Terminal have to draw out nearly all the foul air between Church Street, Erie and Newark Avenue stations, which represents about five miles of tunnel. The passage to Exchange Place elevators acts as an outlet, but only discharges 10,000 cu. ft. per minute.

Of the fresh air that enters the Summit Avenue Station on the Newark line 70 per cent. is returned in the west bound tunnel at Grove Street Station, the 30 per cent. that passes this station is divided between the tunnels going to Church Street and Erie Stations and is approximately 20,000 cu. ft. per minute with trains on 5 minute headway or 40,000 cu. ft. per minute with trains on 2½ minute headway.

To further increase the volume of fresh air entering the downtown tunnels, two blowers were installed at Railroad avenue, Jersey City, having a capacity of 50,000 cu. ft. per minute each. No ducts were required and the frictional resistance is very low, greatly reducing the first cost and the operating expense. The air passes to the four tunnels at this section and is circulated by the trains through the tunnels between Church Street, Newark Avenue and Erie Stations. Dampers are placed at the opening to each tunnel for proper regulation.

The Henderson street entrance of Newark Avenue Station also admits fresh air to the down-town tunnels.

The elevator shaft at Caisson 3 about 500 ft. north of Erie Station used during construction has been reopened to the surface. No air is exhausted at the Erie Station.

The Hoboken Station stairways admit about 50,000 cu. ft. of fresh air per minute. Practically no air is exhausted at the entrances. The 104,000 cu. ft. of air per minute blowing toward Hoboken in the north-bound tunnel goes back into the south bound tunnel at the crossover in Hoboken Station, except 40,000 cu. ft. which is taken out by the exhaust fans.

In the orginal design it was considered necessary to install all fans in duplicate. This idea has now been abandoned, as it has been found quite possible to shut down any fan for a day or more for repairs without appreciably affecting the air in the tunnels.

Installations of large capacity, such as are required for a system of deep tunnels, where access to the surface is only possible at long intervals, the design of the fans and air ducts requires very careful study. If they are not properly proportioned, the ventilation will become a very expensive proposition, both in first cost and in operation.

A test of the quality of air in the tunnel system made by Dr. Thomas B. Stillman, chemical engineer of the Stevens Institute of Technology, showed slightly less than 3.5 parts of carbon dioxide in 10,000.

Samples of air taken in the afternoon rush hour between boats crossing the Hudson River showed an average of 9.4 parts of carbon dioxide

in the women's cabins and an average of 17.6 parts of carbon dioxide in the men's cabins.

Samples taken from the crowded trains of the Hudson Tunnels between 5 and 6 p. m. showed that the amount of carbon dioxide was between 5 and 6 parts only. Air from the tunnels, not taken from the trains, gave 3.5 parts of carbon dioxide, showing it to be as pure as the air outside.

It should be borne in mind that it is just as essential to change the air frequently in order to remove odors caused by the heated oil on the motors of the trains and the dampness which is always present in deep tunnels.

Your Committee is under obligation to Mr. J. Vipond Davies, Chief Engineer, Hudson & Manhattan Railroad Company, for information furnished.

Your Committee presents the foregoing as information, withholding conclusion until experiments now being conducted on single and double-track steam railroad tunnel ventilation are completed.

(4) Economics in Roadway Labor. H. J. Slifer, Chairman; J. A. Spielman, J. E. Willoughby, Frank Merritt, Sub-Committee.

Your Committee having agreed with the Track, Signals and Interlocking Committees on a subdivision of the work, reports progress.

RECOMMENDATIONS FOR 1913.

Your Committee recommends that subjects 2, 3 and 4 be reassigned, again respectfully calling attention to the resolution above referred to.

Respectfully submitted,

COMMITTEE ON ROADWAY.

REPORT OF COMMITTEE XVI—ON ELECTRICITY.

GEORGE W. KITTREDGE, *Chairman;*	J. B. AUSTIN, JR., *Vice-Chairman;*
D. J. BRUMLEY,	W. S. MURRAY,
R. D. COOMBS,	FRANK RHEA,
A. O. CUNNINGHAM,	J. M. REID,
L. C. FRITCH,	A. F. ROBINSON,
GEO. GIBBS,	J. R. SAVAGE,
G. A. HARWOOD,	MARTIN SCHREIBER,
E. B. KATTE,	W. I. TRENCH,
C. E. LINDSAY,	H. U. WALLACE,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee presents herewith its annual report for the year 1912.

Two meetings were held during the year as follows: At New York on May 13, 1912, at which were present Messrs. George W. Kittredge, Chairman; J. B. Austin, Jr., Vice-Chairman; D. J. Brumley, R. D Coombs, G. A. Harwood, A. B. Hill (representing Mr. Geo. Gibbs), E. B. Katte, Martin Schreiber. At New York on February 10, 1913, at which were present Messrs. George W. Kittredge, Chairman; J. B. Austin, Jr., Vice-Chairman; R. D. Coombs, E. B. Katte, C. E. Lindsay, Martin Schreiber, W. I. Trench.

The balance of the work of the Committee has been done by subcommittee meetings and by correspondence.

(1) CLEARANCES.

Your Committee submits the following report as one of progress and information:

This Committee has considered a communication calling attention to interference with the bridge clearance line of the Association by the recently adopted third rail, permanent way structures and rolling equipment clearance lines, and has made a recommendation to the Committee on Iron and Steel Structures that as much of the bridge clearance diagram as interferes with the third rail and permanent way structures clearance line be eliminated, and in place thereof the clearance line for permanent way structures be substituted on roads where electric equipment is likely to be used.

The Committee on heavy electric traction of the American Electric Railway Association submitted a report at the annual meeting held at Chicago in October, 1912, which report recommended clearance lines for third rail, permanent way structures and rolling equipment identical with the lines adopted by this Association at its last meeting, and also submitted for information and guidance a suggested clearance diagram for

automatic stops, with the recommendation that the matter be continued to allow the Committee time to confer with similar committees of this Association and the American Railway Association. The American Railway Association at its meeting in May, 1912, adopted a clearance diagram for third rail, permanent way structures and rolling equipment identical with the diagram adopted by this Association.

The Committee has been following up the progress made during the year on third rail installation and has had the table which accompanied last year's report brought up to date and same is resubmitted as information.

It is urged on the members of this Association that they try and induce their Companies to conform to the clearance diagram on all new work and gradually change over their present installation so that ultimately there can be a free interchange of electric equipment between the various roads.

The Committee has been collecting during the year data in regard to overhead clearances and is studying same with a view of taking up this question during the coming year with committees of the American Electric Railway Association and the American Railway Association, so that joint recommendations for overhead clearance lines may be made by the respective committees of each Association.

The Committee is not prepared at this time to take up the question of clearance lines for automatic stops, but as soon as a device that is adapted to conditions obtaining on roads operated in the open has been perfected, the question of established clearance lines will be further considered.

(2) TRANSMISSION LINES AND CROSSINGS.

Your Committee desires to report progress on the consideration of modifications of the specifications for overhead crossings of electric light and power lines adopted by the Association at the last convention for Transmission Lines and Crossings as will be necessary to cover voltages over 70,000 and also the consideration of the revision of the specifications in paragraphs Nos. 10, 13, 18, 24, 29, 31, 32, 34, 45, 49, 51, 55, 60 and 61, which were adopted by the Association with the understanding that the revision of these particular paragraphs would be considered this year.

Your Committee, however, is not prepared at this time to make any further recommendations for the reason that more time is required to study the development of the art in respect to voltages over 70,000 and further because of the fact that all of the various similar associations have not yet modified theirs or formally adopted ours so as to make uniform specifications. We know of no reason, however, why those that have not should not do so as opportunity for revision comes up. In other words, our specifications are not objectionable.

(3) ELECTROLYSIS.

An invitation has been received from the American Electric Railway Association to unite with them in jointly considering the subject of "Electrolysis," and your Chairman has appointed Messrs. Katte, Gibbs and

Brumley to serve on this Joint Committee with Messrs. Townley, Richey and Palmer, the members appointed by the American Electric Railway Association.

Your Committee submits the following report with recommendations that it be printed in the Proceedings of the Association as information.

Introduction.—The effect of electrolysis upon steel and iron structures, including water, gas and electric conduit pipes, also on the lead sheaths of insulated cables, has been a matter of serious concern ever since the first street car was operated electrically by means of a grounded return, but not until the advent of electrification on steam railroads did the subject become one of much interest to railway engineers. The matter is receiving the careful consideration of electrical engineers in conference with structural engineers and representatives of various municipal departments, but up to the present time there is no unanimity of opinion as to the best methods of preventing electrolysis, or for protecting metal structures adjacent to the path of grounded return circuits. For this reason your Committee cannot recommend any standards or preferred practice, but have compiled for your information a statement of methods pursued and a description of the research work now under way at some of the more important localities of particular interest to railway engineers. The descriptions have been prepared to cover locations as follows: Brooklyn Bridge, Borough of Brooklyn Traction System, Grand Central Terminal, New York City; Pennsylvania Terminal, New York City; City of Chicago Traction System; Bergen Tunnels of Delaware, Lackawanna & Western Railroad; Baltimore & Ohio Railroad Terminal, Baltimore, Md.

In addition to this brief description of actual conditions there has been prepared a short explanation of the phenomenon of electrolysis and the more common methods of preventing its action; also a list of reference books and papers dealing with the electrolytic problem is appended to this report.

NATURE OF ELECTROLYSIS.

Electrolysis as referred to in the Electric Railway discussions may be described as the wasting away or corrosion of a metal which is caused by an electric current passing from one metallic conductor to another conductor where both are buried in damp earth, or other semi-conducting medium.

CAUSES AND EFFECT OF ELECTROLYSIS.

In direct current railway circuits the electric current passes from the power station or substation to the trolley wire or third rail, then through the motors of electric cars or locomotives and back to the station by the track rails. Owing, however, to the fact that it is practically impossible at all times to insulate the rails adjacent to the ground, part of the current leaks into the earth and finds its way back to the station through the ground, and in doing so, if pipes, cable sheaths or steel work are

under or adjacent and parallel to the tracks, some of it may return by these metallic structures.

At some point or points this current must leave these metallic structures and usually does through the earth in the neighborhood of the power station or substation, causing electrolytic effects in the underground structure or conductor at the points in question, unless precautions have been taken, as later indicated.

There is less opportunity for current to escape from the tracks on electrified roads where the rails are above ground and rest on wooden ties in ballast and there is no opportunity for such escape where the return circuit does not enter the running rails but is conducted back to the power station by independent and insulated contact rails or wires. Examples of this method of construction are found in slot conduit street railways and those having double overhead trolleys; also in those using a separate insulated return conductor rail.

It is common practice to connect the negative bus-bars in the power station or substations with the running rails by copper cables at the points nearest to the stations. Such a connection is shown in Fig. 1. Leakage of current from the rails to the adjacent water pipes along the line may thus occur and the current flowing in these pipes leaves them and returns to the rails in the neighborhood of the power station, causing electrolysis at the points where it passes from the pipes through the earth.

PREVENTION OF ELECTROLYSIS.

It is possible to prevent electrolysis by precluding the escape of electric current from the return conductors, but frequently this is not practicably possible as in the case of buried rails carrying return current. Several methods of meeting this latter condition have been employed, briefly described as follows:

(a) *Drainage System.*—In order to prevent this escape of current into the earth, negative cables are sometimes run from the power station or substation to adjacent pipes or metal work so that the current will leave these structures through metallic paths, thus preventing electrolysis at such points. This system is successfully used in connection with continuous cable sheaths or pipe lines having screw joints, although it results in inducing a larger volume of flow by these paths. It is objectionable, however, in water pipe lines having lead joints, as frequently electrolysis is induced at the pipe joints as shown in Fig. 2. This method of reducing electrolysis is known as the Drainage System.

(b) *Insulated Negative System.*—Another system employed is to provide insulated cables which are connected to the rails at points remote from the station. This style of connection is shown in Fig. 3. It is largely employed in Europe and is beginning to be specified in connection with the American systems. This has the effect of maintaining a more uniform and lower negative potential and largely prevents the current from leaving the bonded rails. The objection to this system

is the high cost of the insulated copper cables, which must be relatively very large and which do not carry current to their full capacity.

(c) *Booster System.*—A modification of the above system devised to compel the cables to carry current to their full capacity is known as the Booster System. In this system the cables carrying return current are connected to a low potential generator of large capacity which acts like a pump placed in a pipe line of low flow head to increase the volume of flow. This style of connection is shown in Fig. 4.

(d) *Other Systems.*—There are sometimes peculiar local conditions of which advantage can be taken by an electrical engineer, but usually one or the other of the above systems, or combinations of them, are employed to safeguard metallic structures adjacent to the path of the return current.

BROOKLYN BRIDGE—NEW YORK CITY.

The first heavy electric traction system in New York City was installed on the Brooklyn Bridge. The power was used principally to switch trains into position to grip a propelling cable. The current demand was usually small and no serious electrolytic problem arose. When, however, the trolley cars and electrified elevated trains crossed the bridge, the situation changed. The return current leaked to the bridge structure and streamed back to Brooklyn by all metallic paths, some even returning through the water of the East River. In 1900, sixty observation stations were established and as a result the bridge structure, particularly the cables were heavily bonded to the traction tracks at the Brooklyn end and the voltage of the structure at the danger end was reduced.

BROOKLYN TRACTION SYSTEM—BROOKLYN, N. Y.

Attention was first called to the general electrolysis situation in Brooklyn by the report of the Board of Commissioners of Electric Subways, dated October 31, 1896. At that time the surface cars, which were the only ones electrified, were fed from several central power stations. When substations were installed, made necessary by the electrification of the elevated roads and increased surface traffic, they were naturally placed where the positive and negative drop was the greatest, and the shortening of the negative circuits greatly improved conditions. Having completed a system of substations, a survey of the city was made and plans prepared to reduce the drop in the return circuit to 3 per cent. by the installation of copper returns. This plan was not fully carried out in view of the high cost, but the approximation proved so satisfactory that with later additions of substations and feeders, no serious electrolysis problem has developed in Brooklyn.

GRAND CENTRAL TERMINAL—NEW YORK CITY.

General.—In the Grand Central Terminal there are thousands of columns supporting terminal yards, streets and buildings and in the midst of them there is operated an electric railway with a grounded return.

It is obvious that the means for adequately protecting this immensely valuable property must be most complete. This situation was early recognized and steps were taken as follows:

(1) A substation was located in the Terminal. This was done primarily to reduce the transmission losses, but it also made possible the maintenance of the structural steel at a low potential—a most important circumstance, as will appear later.

(2) This substation was connected to the return rails by seven (7) 2,000,000 c.m. cables, which in consequence of their short length provided a return circuit of very low resistance.

(3) Independent negative cables were connected to the terminal steel and the Post Office Building, the first of the group of buildings which will cover the Terminal.

(4) A system of inspection, in the nature of an electrolytic survey, was established with regular dates for inspections and a prescribed form of report.

Such precautions were adequate during the early stages of construction, but as additional steel was erected, the ratio of the resistance of the copper to the steel was steadily falling and the protection correspondingly became less effective.

Volt Meter Method.—The early electrolysis survey consisted of taking readings of the potential between the steel structure and the adjacent tracks, pipes, etc., and noting the direction of the flow. It was realized, however, that the difference of potential method was not satisfactory. For should a potential of four volts exist between a column and an adjacent pipe, it might be assumed that the situation required immediate attention, whereas if only one-tenth of a volt existed, the condition would be regarded as entirely satisfactory. As a matter of fact, if the four volts were due to there being good insulation between the columns and the pipe with no flow of current there would be no electrolytic action, while on the other hand, if the one-tenth volt was due to a low resistance path over which a large volume of current was flowing, electrolysis would surely be taking place. In other words, the readings indicated only the potential difference between two points of a circuit and the important factor, the amount of current flow, was unknown. Appreciation of the incompleteness of this system of readings, which, however, is the one in common use, lead to the development of a new method, briefly described as follows:

Galvanometer Method.—The problem in the Grand Central Terminal is to protect the column bases. It is accepted that when current flows upwards from a column foundation that this column is free from any possible electrolytic damage. If, however, it flows downward to the foundation, then electrolysis is possible and it becomes important to know the volume of the current. There is one other condition, when the current reverses, sometimes flowing upward and sometimes downward. With equal reversals of current electrolysis is only one-thirtieth as destructive as when persisting in one direction. Because of the large

sections of the Grand Central Terminal steel and the small current flowing, it was impossible with the instruments in common use, to determine either the direction of flow or the volume of current. After investigation and experimental work a special portable galvanometer was constructed that would read to three-millionth (.000003) of a volt, per division. Reading points were established five feet apart on the columns to be surveyed, the concrete protection being pierced and the steel columns drilled, a ¼-in. pipe inserted and the terminals of the instrument attached. The sketches shown on Plate II clearly illustrate the method of making the contacts. By this method, it has been possible to obtain readings on columns having a resistance as low as two hundred and thirty-five millionths (.000000235) of an ohm between terminals and current flows as low as one ampere in such a column can be read and its direction determined. The instrument has not proven too delicate for practical use.

A complete electrolytic survey of the Terminal has been made and the current flow in each column measured, its direction ascertained and the data plotted. In general, the steel was found to be in a state of balance; current flowing up some columns, down others, and reversing in many of them. Such being the case, it appears that without much change the balance can be deflected to the safe side by making the current flow up all the columns, all the time, and that condition made permanent.

Upward Drainage System.—To effectually drain the steel structure and cause all current to flow up the columns, it is first necessary to directly connect the steel deck and the upper tracks with the substation negative bus by short cables of large cross-section; second, remove all metallic connections between the tracks and the steel structure. In view of the enormous section of this steel and the small current it carries, the steel work may be at a slightly higher potential than the substation negative bus and all escaping current will tend to flow towards it, which is in the harmless direction. However, to make sure and to accentuate this action, especially at the column bases, it is proposed by an arrangement of circuits to raise the potential of the lower level track rails so that at all times they and the surrounding earth will be strongly positive to the columns, thus preventing any flow of current from the columns into the earth without which there can be no electrolysis.

Work in Progress.—The above described plans of reducing the potential of the structure and draining it upward to the substation is now in course of execution. The water pipes and gas pipes crossing the Grand Central Terminal are carried on wooden supports and insulated from the steel structure, and when the work is completed all such pipes and their connections will be insulated from the steel structure and the negative conductors.

Actual Conditions.—Recently the bases of some of the columns were exposed for examination and although some rusting was found, there

was no distinct evidence of electrolysis. These columns have been in place carrying electrified track for six years.

Research Work. An Experimental Electrolysis Investigation has been started to determine the best means of protecting future structures by various compounds and processes and to determine the amount of electrolysis per square foot of steel per year under a given flow of current when the steel is painted and enclosed in concrete in accordance with standard practice. The form of the test unit is shown in Plate III. No results have yet been recorded.

PENNSYLVANIA TERMINAL—NEW YORK CITY.

General.—This system is operated with a grounded return and no attempt has been made to insulate the negative conductors from the ground. In our return circuits, we use both track rails, except at interlockings.

Cables.—All lead-covered cables in each manhole are covered with asbestos and steel tape and the lead sheaths bonded together. The sheaths of all cables are bounded to the negative wires at each substation; in order to take the current flowing in the sheaths back over a cable and thus prevent damage by electrolysis. The sheaths almost without exception are negative to tracks and tunnel linings. We have 25 cables, including high and low tension, control and telephone cables leaving the power house, and two 5,000,000 c.m. bare negative cables connecting the negative bus in the substation with the rails at the nearest point to the power house. The lead sheaths of the above cables are equivalent to about 2,400,000 c.m. of copper. We have had only two cases of trouble caused by electrolysis of lead sheaths and have remedied same by locally bonding them at points of outflow of current.

Track Rails.—We have made a number of examinations of the rails, tie-plates and screw spikes at various points on the system, but have found no serious trouble. The rails and tie-plates are found to be in good condition at all points.

Air and Water Piping.—We have had no trouble with water pipes, which run parallel with the tracks. The signal air pipes are carrying considerable current at times, due to insufficient cross-bonding between the tracks in one of the yards. This trouble is being remedied by bonding at local points and by installing additional cross-bonding between tracks.

Structural Steel.—We have made regular investigations to determine the amount of current on the steel columns and girders in the station area and find almost no current flowing. No trouble has developed and we have not found any indications to lead us to expect any trouble.

Conclusions.—We test our track bonds every year and look after the cross-bonding frequently. Very few bad bonds are found. Provision is made at each substation to find the amount of current carried on the cable sheaths. Readings of these amounts are taken frequently and when any material increase or decrease in these amounts is found the matter

is looked into. By keeping our cable sheaths bonded together and negative to tracks and iron, we do not anticipate any trouble from electrolysis.

CITY OF CHICAGO TRACTION SYSTEM.

Electric propulsion at the present time is restricted to the operation of surface street car lines and elevated railroads for passenger traffic, and a tunnel of small section for the transportation of package freight.

The approximate track mileage on this classification is:

Surface street car lines	915	miles
Elevated railroads	160	"
Illinois Tunnel	65	"
Total	1,140	"

The power plants and substations of these transportation lines—thirty-four in number—extend from Eighty-third Street and South Chicago Avenue on the southeast, and Eleventh Street and Michigan Avenue on the south, to Evanston Avenue, north of Ardmore on the north, the most westerly being at 117 South Lombard avenue, near South Boulevard. The area bounded by lines drawn through the outlying sections is approximately eighty-nine square miles or 46½ per cent. of the area of the city. The location of these substations, referred to the City Hall as a center, is:

Included within a radius of 1 mile							5
Between lines		1	and	2	miles	distant	5
"	"	2	"	3	"	"	3
"	"	3	"	4	"	"	4
"	"	4	"	5	"	"	3
"	"	5	"	6	"	"	6
"	"	6	"	10	"	"	6
"	"	10	"	13	"	"	2

The mean level of Chicago is but a few feet above the mean level of Lake Michigan and the Chicago and Calumet Rivers. Most of the soil in which water pipes and public service cables are laid is unconsolidated material, consisting of boulders, clay and sand. Chemical analysis shows that the components of the soil are, as a whole, not damaging to iron or steel work, although the filled districts, comprising but a very small percentage of the total area, may contain elements which contribute toward rapid deterioration of iron and steel work.

For a number of years the telephone, lighting and power companies have kept a force of men in the field working continuously toward protecting their properties from stray current damage.

The problem of reducing the damage to water pipes and other city structures by electrolysis has been made the subject of special study by the city. The damage to water pipes is covered quite fully in a special report made by the City Engineer to the City Council in November, 1911. This report shows that the failure of water pipes in the districts covered by the special investigation is very great. There is no practicable way

to determine how much of the loss is directly due to damage caused by electrolysis, but it is apparent from a study of electrolytic conditions where leakage occurs that the loss from this source of damage is very great.

In addition to the survey of the condition of water pipes and other city structures, surveys have been made to determine the voltage and amperage between return circuits of electrically operated railroads and water pipes, city bridges, buildings, and public service cables. The result of the electrolysis surveys conducted by the Consulting Engineer was referred to the City Council in November, 1911. The scope and recommendations of the Consulting Engineer may be briefly stated as follows:

The surface railway districts surveyed are:

(1) That section of the city bounded by North Avenue on the north, Lake Michigan on the east, Madison Street on the south, and the Chicago River on the west, containing 2.60 square miles and including four stations or substations.

(2) That section of the city bounded by Belmont Avenue on the north, Lake Michigan on the east, North Avenue on the south, and the Chicago River on the west, containing 4.30 square miles, and including two stations or substations.

(3) That section of the city bounded by Thirty-first Street on the north, Lake Michigan on the east, Fifty-fifth Street on the south, and Halsted Street on the west, containing 7.64 square miles and including two stations or substations.

The survey of the elevated railroads includes all those within the city limits.

The conclusions reached by the Consulting Engineer may be briefly stated as follows:

(1) That too little thought has been given to the electrolysis problem.

(2) That water pipe mains have been seriously damaged in certain districts and that they, with other subsurface metallic structures, including cable sheaths, bridges, structural steel buildings, are being damaged by electrolysis.

(3) That most of this damage is caused by the surface, elevated and tunnel companies' electric return currents, which leak or stray from the rails of return conductors to these metallic structures.

(4) That a great part of this damaging current leakage is due to insufficient or defective return conductors.

The recommendations of the Consulting Engineer to the City Council are:

(1) Modify the present city ordinance on grounded or railway return wires. This may be accomplished by the following methods:

(a) Reconstruct all defective track work and install additional return feeders.
(b) Install a negative booster system.
(c) Install a return current drainage system.
(d) Reduce the size of the power plant and substation feeding districts.
(e) Insulate the railway return circuits.

(2) Co-operation between city, railway and public utility companies for the completion of this survey work.

The report on damage to water pipes by the City Engineer and the electrolysis report by the Consulting Engineer have been given most careful consideration by the City Council. The question of modifying the city ordinance was under discussion by the Gas, Oil and Electricity Committee until July 15, 1912, when an ordinance was passed requiring certain electrical equipment in order to prevent damage by electrolysis. The ordinance passed by the City Council July 15, 1912, provides:

Section 1. All insulated electrical return circuits must be of such current carrying capacity and so arranged that the difference of potential between any two points on the return will not exceed the maximum limit of 12 volts and between any two points on the return 1,000 feet apart within one mile radius of the City Hall, will not exceed the limit of one volt, and between any two points on the return 700 feet part outside of this one mile radius limit will not exceed the limit of 1 volt. In addition thereto a proper return conductor system must be so installed and maintained as to protect all metallic work from electrolysis damage.

The return current amperage on pipes and cable sheaths must not be greater than 5 amperes per pound foot for caulked cast-iron pipe; 8 amperes per pound foot for screwed wrought-iron pipe, and 16 amperes per pound foot for standard lead or lead alloy sheaths of cables.

Section 2. All persons, firms or corporations operating railways must equip their uninsulated return current systems in the following manner:

(a) With insulated pilot wire circuits and volt-meters, so that accurate chart records will be obtained daily showing the difference of potential between the negative bus bars in each station and at least four extreme limits on the return circuit in its corresponding feeding district.

(b) With recording ammeters, insulated cables and automatic reverse load and overload circuit breakers which will record and limit the maximum amperes drained from all metallic work (except the regular return feeders) to less than ten per cent. of the total output of the station.

At the present time the surface lines and elevated railroads, together with other public utilities, are making a study of the condition of return circuits. A committee representing the surface lines, elevated railroads, Peoples Gas, Light & Coke Company, Commonwealth Edison Company, Chicago Telephone Company and Board of Supervising Engineers, is making a study of the matter, but the results of their conclusions have not been made public, and the conditions found on return circuits of the surface railways and elevated railroads are not available at this time.

THE BERGEN TUNNELS OF THE DELAWARE, LACKAWANNA & WESTERN RAILROAD AND THE ERIE RAILROAD.

In order to give an idea of the physical condition surrounding this particular location, it should be explained that the Delaware, Lackawanna & Western Railroad Company have cut a second tunnel through Bergen Hill, paralleling their original brick-lined tunnel. Both run in an easterly and westerly direction and are approximately 4,000 ft. in length. The east portals are in the city of Hoboken, N. J., and the west portals are in Jersey City, N. J. The tunnels are through trap rock strata prevailing in this section of country. The floors of the tunnel lie approximately 50 ft. to 125 ft. below the surface contour. About one-third of the distance inward from each portal a vertical cut has been made from the top surface to the tunnel floor, dividing the tunnel into three sections. Midway of each section an air shaft has been let from the top surface through the crown of the concrete-lined tunnel A retaining wall, forming the sides and arched roof of the tunnel, as well as facing the open cuts and air shafts, is about two feet in thickness.

The concrete facing is made in sections and no homogeneous union of the concrete exists at the joints between sections. No reinforcing has been used in the construction of the concrete walls, except a large mesh screen, suspended from eye-bolts driven into the rock, to which were fastened the construction forms. Throughout the surrounding rock strata streams of water ramify, more or less of this water escaping into the tunnel, principally through the voids at the joints of the concrete sections. One of the Jersey City reservoirs is situated on top of Bergen Hill, the south retaining wall of which is a short distance from and parallel to the tunnel for a portion of its length, east of Central Avenue.

Two concrete foundations support the two tracks throughout the length of the tunnel. Under each track is a duct containing signal wires, lead-covered telephone cable or lead-covered A. C. power cable. A 16-in. water main is laid parallel to the north wall of the tunnel throughout its length. An iron pipe conduit for lighting wires is imbedded in the concrete wall near the turn of the arch on each side. This iron conduit runs in sections of approximately 300 ft. to common junction iron boxes let in the side of the wall about 4 ft. above the tunnel floor.

The Public Service Railway Company has trolley lines within a long radius of the vicinity of the tunnel and to which power is supplied from a substation at Palisade Avenue, approximately one-quarter of a mile away. Tests were made with suitable instruments between the various structures embedded in the concrete walls and some of the electric conductors, or metallic returns as were accessible in the tunnels. The relation of the lighting conductors of the tunnels were separately investigated. These tests, made by this company's representatives, will not be described in full, as the ordinary methods of carrying them on are well-known, but suffice it to say that in all cases the difference in potential was very small, and when a short circuit path was established between

any test points only a fraction of an ampere of current was found. Moreover, when the substation at Palisade Avenue was closed down during periods of least normal traffic over the whole general system, practically the same drop existed throughout the tunnel.

From investigations of this particular example it seems fair to assume that any damage to the concrete by scaling, or otherwise, was not due to the electric current. Also that concrete permeated with moisture is a fairly good conductor, while dry concrete is a poor electric conductor; that metal buried in damp concrete tends to establish a path through which a current of electricity may flow. These principles bear out the facts as found in the latest investigations of the electrical effect of stray currents on reinforced concrete structures.

BALTIMORE & OHIO RAILROAD—BALTIMORE, MD.

General.—Electric propulsion is in use on the Baltimore & Ohio Railroad from the vicinity of its power house just west of Camden Station, Baltimore to Waverly, 3.73 miles east; 1.11 miles of this line is four-tracked, the rest being double-tracked. Within the electric territory there is a total of 1.79 miles of tunnel, the longest of which is Howard Street Tunnel, 7,340 ft. in length.

Railroad Conditions.—The grade varies from 1 per cent. to 1½ per cent. towards the east. Two motors drawing 5,000 amperes under maximum tonnage of 2250 tons are used on the trains up the hill, eastbound. Westbound trains drift through the tunnel, the motors returning light. The track is well-constructed of 100-lb. rail on good ties and clean stone ballast. The subsoil consists of heavy clay and is in places wet. Drainage conditions are good. The track is high and dry and conditions are such as to discourage the escaping of currents as much as are usual in track circuits. In Howard Street Tunnel drainage is effected by a conduit between the tracks, the track being carried on stone ballast; this in turn on one-man stone, the latter resting on the inverted arch of the tunnel. Conditions here are generally wet. There is a heavy seepage of water through the walls of the tunnel, which in places saturates the ballast and ties, the water escaping through the ballast to the conduits between tracks.

Electric System.—The electric system is direct current, 750 volts, third rail contact, and return through running rails. The power is supplied at two points; the Company's power house at Camden and the substation at Mt. Royal, at which purchased power is furnished. The positive conductor consists of 100-lb. R. B. section rail placed in 1912 in Howard Street Tunnel, and 80-lb. Mexican Central rail placed in 1901 over other parts of the line. Previous to the renewal of third rail in the tunnel in 1912, 1901 Mexican Central 80-lb. rail had been in use. The renewal was made necessary by the corroded and eaten condition of the rail, especially at wet points, where one-third of the rail section had disappeared. Previous to the renewal, the insulation and bonding had

not been of the best, having greatly deteriorated since installation. The eastbound third rail is reinforced by two 1,000,000 c.m. copper cables from the power house to Huntington Avenue, laying in close contact with its base. The westbound rail is not reinforced. The east and westbound third rail are cross-bound every 300 ft. in the tunnel and every 1,000 ft. over the rest of the territory. The third rail is bonded at the joints with the two 500,000 c.m. copper bonds. The negative conductor consists of the running rail, 100-lb. R. R. Titanium in Howard Street Tunnel and 100-lb. A. S. C. E. Bessemer on the other parts of the line. The rails are reinforced through the four-track territory and through Howard Street Tunnel by a 1,000,000 c.m. copper cable. This cable is uninsulated and is covered with stone ballast laying between tracks throughout the four-track territory and on the footing course of the tunnel throughout Howard Street Tunnel. It was installed in 1901, and has been much patched on account of deterioration. The running rails and negative cable are cross-bonded every 1,000 ft. The rail joints are bonded with one 500,000 c.m. copper bond. The negative bus bars at Camden power house and Mt. Royal substation are connected with the negative conductor and neither is grounded at the respective points in question.

Electrolysis.—The evidence of electrolysis observed has been the corroding and eating away of negative conductors. The running rail now in Howard Street Tunnel, laid in 1910, already shows pitting at points where ties are saturated and is eaten away slightly at spikes. The rail removed from the tunnel in 1910 had been in the track for three years only and was so far corroded and eaten at the base that its removal was necessary. Just how much the gases of the tunnel assisted in the deterioration of the rail, we are unable to say. Outside the tunnel where the gas factor does not exist and where the drainage is good, there is still unmistakable evidence of electrolysis. The rail here was laid in 1906 and 1908. Its base is pitted and eaten away, especially in the vicinity of the spikes where a semi-circle of metal has disappeared about each spike. The spikes themselves deteriorate rapidly, requiring renewal about once in two years, in some cases the head entirely disappearing in this time. The 1906 rail is intended for renewal next year. It appears that we are getting about twice the life out of the rail in the electric zone outside the tunnel that we are getting in the tunnel, and that the renewal in both cases is due to the action of electric currents rather than mechanical wear. Data on electrolytic action on neighboring water and gas pipes caused by escaping currents from the Baltimore & Ohio Railroad System are meager, no survey having been made. The city water works several years ago made connection between their pipes and the negative conductors at the power house in order to concentrate the discharge from their pipes, but how serious the difficulty was they were trying to remedy or the result of the connection is unknown. Two years ago, so much difficulty had been experienced in maintaining the

Company's water pipes at Mt. Royal that these also were connected electrically to the negative conductor. Time enough has not yet elapsed to note the effect. A neighboring railroad has several times complained of injury to their water pipes at North Avenue and various arrangements for improving our negative conductors have been resorted to, but the trouble has not yet been eliminated. What its extent is, we are unable to say. A test shows Baltimore & Ohio rail four volts negative to pipes at this point, except when motors are passing when Baltimore & Ohio rail is five volts positive to pipes. Connection will probably be made between pipes and negative return of Baltimore & Ohio circuit. Nothing definite can be shown regarding stray currents from Baltimore & Ohio rails until survey has been made.

HISTORY.

The Bibliography of Electrolysis is quite extensive and we have tabulated the principal publications which apply to this class of electrolytic investigation. A copy accompanies this paper for the use of those interested.

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Your Committee has nothing to report on the subjects of (4) Insulation, (5) Maintenance Organization, (6) Relation to Track Structures.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

The Rules and Regulations of the National Fire Protection Association are frequently used by the National Board of Fire-Underwriters in formulating Rules and Instructions for the guidance of their Inspectors, and since the wiring and other electrical work of the Railroad Companies must conform to the Rules and Requirements of the Underwriters' Association, it is the recommendation of your Committee that a representative of the Association be delegated to serve with the National Fire Protection Association.

Your Committee respectfully recommends the continuation of work already outlined, particularly consideration of "Clearance for overhead third rail working conductors and automatic safety stops," "Electrolysis" and "Insulation" and the consideration of any new information that may develop in reference to "Maintenance Organization" and "Relation to track structures," and asks for such other directions or instructions as seem necessary or desirable.

Respectfully submitted for the Committee,

GEORGE W. KITTREDGE,
Chairman.

DATA REGARDING THIRD RAIL CLEARANCES.

Revised January 15, 1913.

Name of Company	Plan No.	Top or Under Contact	Protected	Uses Steam Equipment	Structures Clear Prop. Lines	Mileage in Operation	Mileage Planned for Immed. Future	Mileage Using Steam Equipment	Mileage Clearing Proposed Lines	Remarks
Albany Southern	1	Top	No	Yes	Yes	65.00	.....	65.00	65.00	.....
Aurora, Elgin and Chicago	2	Top	No	Yes	No	95.00	.....	95.00	.....	7.70 Miles O. H. Trolley.
Baltimore & Ohio	3	Top	Yes	Yes	Slight	8.70	.....	8.70	8.70	.....
Boston Elevated Ry	4	Top	No	No	No	33.81	.....	.....	.....	.....
Brooklyn Rapid Transit	5	Top	No	No	No	87.99	.....	.....	.....	49.83 Miles O. H. Trolley.
Northwestern Elevated, Chicago	6	Top	No	No	No	60.00	.....	10.00	.....	16 Miles O. H. Sliding Contact.
Central California Traction	7	Under	Yes	Yes	Yes	70.00	.....	70.00	70.00	27 Mi. O. H. Trolley, inc. in 70 Miles.
G. R., G. H. & M	8	Top	No	No	No	31.26	.....	.....	.....	10 Miles O. H. Trolley-Urban.
Hudson & Manhattan	9	Top	Yes	No	No	18.76	.....	.....	.....	Subway.
Interborough Rapid Transit	10, 11, 12	Top	Partly	No	No	203.36	.....	.....	.....	Elevated 118.0. Subway 85.36.
Lackawanna & Wyoming Valley	14	Top	No	Yes	No	44.00	.....	44.00	.....	5 Miles O. H. Trolley.
Long Island R. R	13, 18	Top	Yes	Yes	Yes	186.80	18.20	186.20	186.20	.....
Metropolitan West Side, Chicago	6	Top	No	No	No	51.08	.....	.....	.....	Elevated.
Michigan United	16	Top	No	Yes	No	107.00	.....	107.00	.....	.....
Nor. Electric Ry., Chico, Cal	17	Top	No	Yes	No	130.00	42.00	130.00	.....	18.79 Mi. O. H. Trolley & Pantograph.
P. R. R., Manhattan Division	18	Top	Yes	Yes	Yes	70.93	.....	70.93	70.93	1.63 Mi. O. H. Contact included in total.
Puget Sound Electric Ry	19	Top	No	Yes	No	37.50	.....	37.50	.....	10.0 Mi. O. H. Trolley-Urban.
Philadelphia & Western	20	Under	Yes	Yes	No	34.00	.....	34.00	.....	1.50 Mi. Trolley in Yards.
Scioto Valley Traction Co	21	Top	No	Yes	Yes	66.50	.....	66.50	.....	3.86 Mi. Trolley-Urban.
P. R. R., New York Division	.....	Top	Yes	Yes	Yes	27.45	.....	27.45	27.45	.....
South Side Elevated, Chicago	6	Top	No	No	No	46.41	.....	.....	.....	0.6 Mi. at Yard Leads.
P. R. R., West Jersey & Sea Shore	23	Top	Yes	Yes	Yes	150.26	.....	150.26	150.26	8.65 Mi. O. H. Trolley included in total.
Wilkesbarre & Hazelton	24	Top	Yes	Yes	Slight	29.50	.....	29.50	.....	1.50 Mi. O. H. Trolley.
N. Y. C. & H. R	26	Under	Yes	Yes	Yes	185.89	52.70	185.89	185.89	1.6 Mi. O. H. Conductors.
Detroit River Tunnel Co	26	Under	Yes	Yes	Yes	19.27	.....	19.27	19.27	New station will require add 3rd Rail.
Phila. Rapid Transit Co	.....	Under	Yes	No	No	18.61	.....	.....	.....	Subway & Elevated Lines.
Oneida Railway Co	25	Under	Yes	Yes	Yes	103.47	.....	96.23	103.47	8.95 Mi. O. H. Trolley.
						1982.55	112.90	1433.43	887.17	

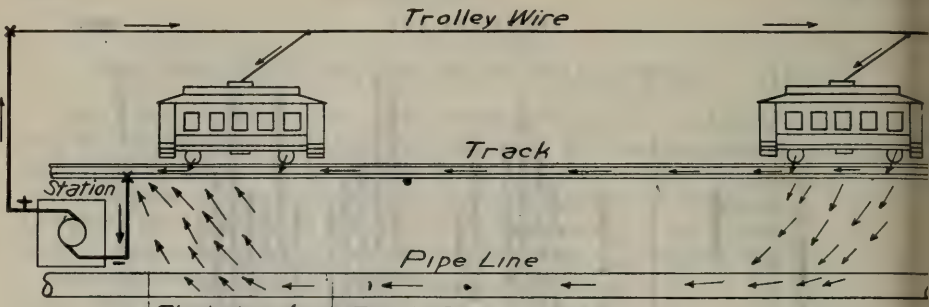


Fig 1-Common Practice

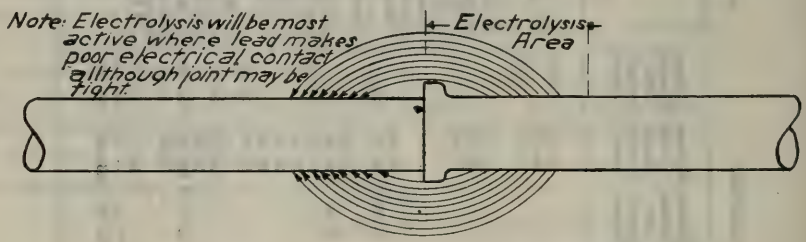

Note: Electrolysis will be most active where lead makes poor electrical contact although joint may be tight
Electrolysis Area

Fig 2-Electrolysis at Pipe Joint

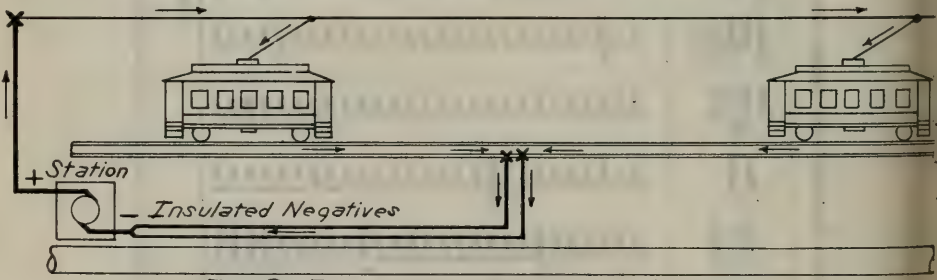


Fig 3-Insulated Negative System

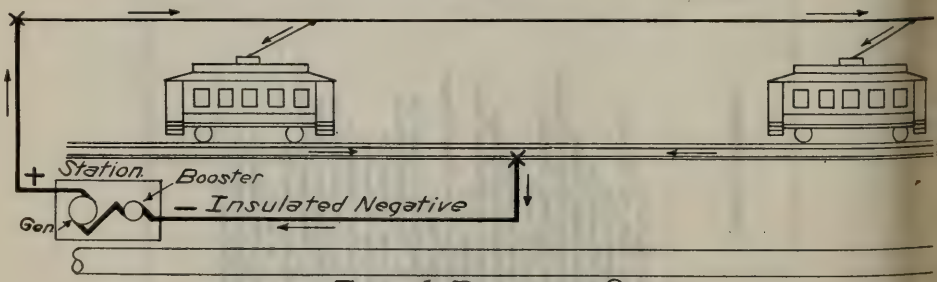
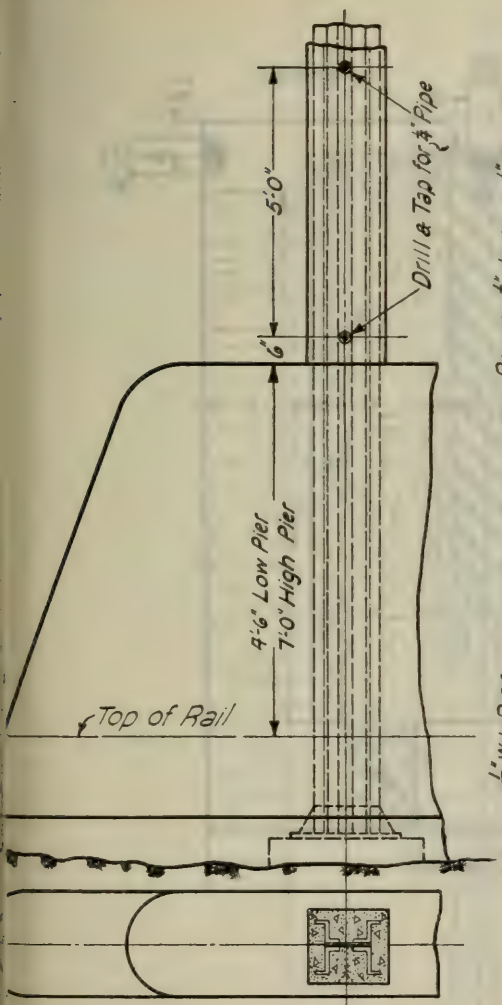
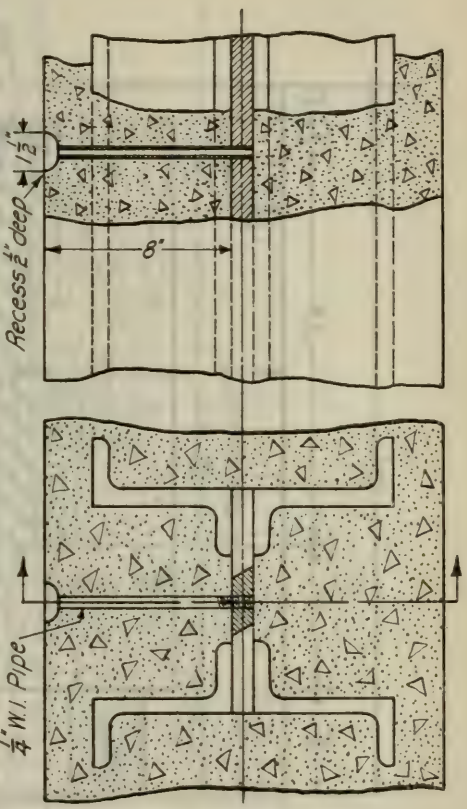


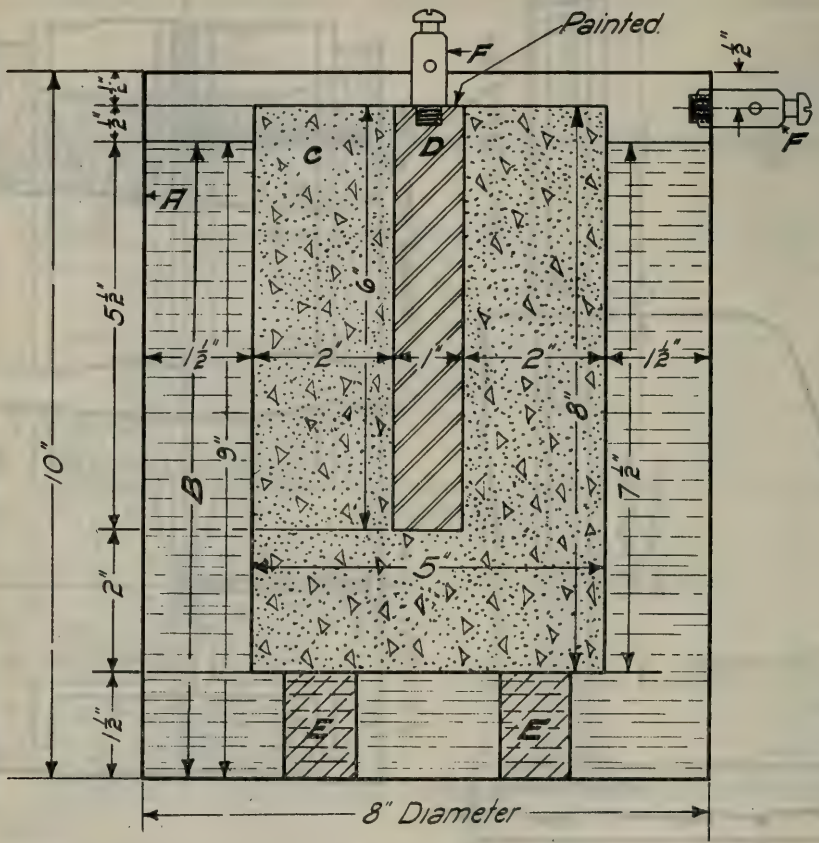
Fig-4 Booster System





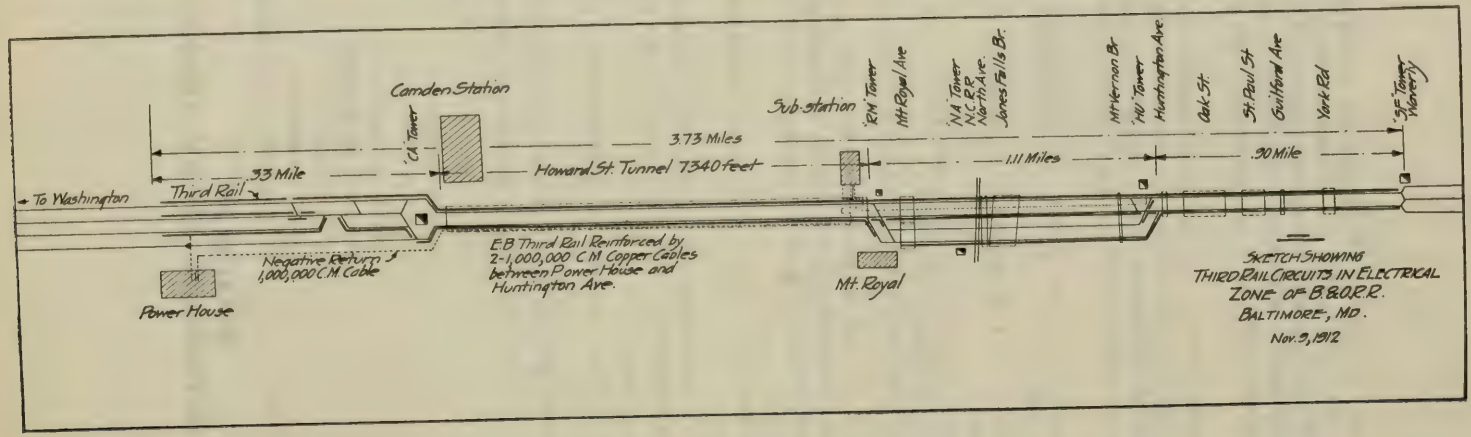
Note: Drill & Tap on Neutral Axis of Web on West or South Side of Column according to type.

N.Y.C & H.R.R.R.
ELECTRICAL DEPARTMENT
COLUMN CONTACT TERMINALS
FOR ELECTROLYSIS READINGS

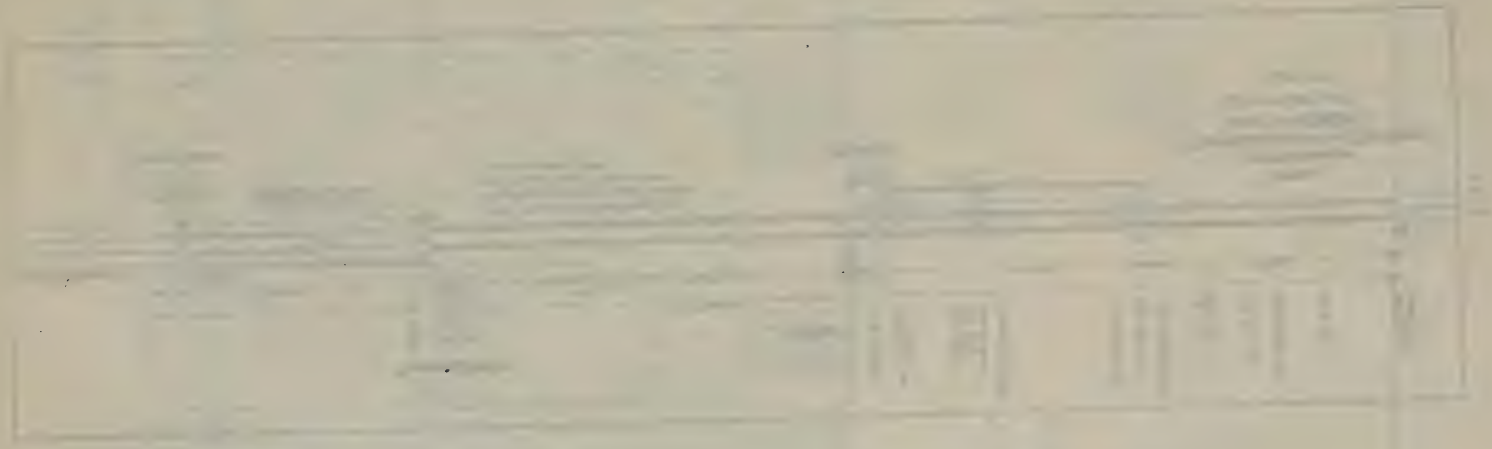


A—Tin Pail.
B—Electrolyte
C—Concrete Cylinder
D—Iron Bar
E—Porcelain Supports.
F—Terminals.

N.Y.C. & H.R.R.R.
ELECTRICAL DEPARTMENT
ELECTROLYSIS TEST UNIT. TYPE "I."


Camden Station
'CA' Tower
Sub-station
'RM' Tower
Mt Royal Ave
'NA' Tower
N.C.R.R.
North Ave
Jones Falls Br.
Mt Vernon Br.
'MV' Tower
Huntington Ave
Oak St.
St. Paul St.
Guilford Ave
York Rd
'SF' Tower
Waverly
3.73 Miles
.33 Mile
Howard St. Tunnel 7340 feet
1.11 Miles
.90 Mile
To Washington
Third Rail
Negative Return 1,000,000 C.M. Cable
E.B. Third Rail Reinforced by 2-1,000,000 C.M. Copper Cables between Power House and Huntington Ave.
Power House
Mt. Royal
SKETCH SHOWING THIRD RAIL CIRCUITS IN ELECTRICAL ZONE OF B.&O.R.R. BALTIMORE, MD.
Nov. 9, 1912

1011



REPORT OF COMMITTEE XI—ON RECORDS AND ACCOUNTS.

H. J. Pfeifer, *Chairman;* M. C. Byers, *Vice-Chairman;*
J. M. Brown, W. A. Christian,
Edward Gray, G. J. Graves,
E. E. Hanna, Orlando K. Morgan,
Henry Lehn, Walt. Dennis,
J. H. Milburn, G. D. Hill,
C. W. Pifer, Frank Ringer,
Guy Scott, *Committee.*

To the Members of the American Railway Engineering Association:

Your Committee on Records and Accounts respectfully submits herewith its report:

The Board of Direction assigned the following work to your Committee for the current year:

(1) Make a comprehensive study of the forms in the Manual, which were adopted a number of years ago, and bring forms up to date.

(2) Continue the study of the economical management of store supplies.

(3) Recommend feasible and useful subdivisions of Interstate Commerce Commission Classification, Account No. 6, with a view to securing uniformity of labor costs.

The Sub-Committees were appointed by the Chairman after consultation with the Vice-Chairman, as follows:

Sub-Committee No. 1—Guy Scott, Henry Lehn, J. H. Milburn and Orlando K. Morgan.

Sub-Committee No. 2—J. M. Brown, G. J. Graves, E. E. Hanna, G. D. Hill and Edward Gray.

Sub-Committee No. 3—Frank Ringer, W. A. Christian, Walt. Dennis and C. W. Pifer.

Two meetings were held during the year, one at St. Louis on December 17, 1912, attended by Messrs. Byers, Brown, Hill and Pfeifer, and the other at the offices of the Association in Chicago, January 17, 1913, attended by Messrs. Byers, Brown, Christian, Dennis, Graves, Hill and Pfeifer.

After a conference with the Vice-Chairman of the Committee, and the approval of the Board of Direction, the Chairman on behalf of the Committee invited the Railway Storekeepers' Association to appoint a representative to co-operate with the Committee in the discussion of Subject No. 2. Mr. E. J. McVeigh, Storekeeper, Grand Trunk Railway,

Ottawa, Can., Chairman of their Committee on Recommended Practice, was elected. He attended the Committee meetings at St. Louis and Chicago, and gave the Committee most valuable aid in reaching its conclusions.

CONCLUSIONS.

SUBJECT NO. 1.

Some of the forms, particularly those used in connection with the accounts, such as foremen's reports of labor and material consumed, might be changed in some particulars, but it is doubtful if such changes would bring about their more general use by the railroads, as little, if anything, would be gained by suggesting minor changes in these forms. It is the opinion of the Committee that no changes be made at the present time in the forms appearing in the Manual. It is suggested that since the selection of the proper forms for time books, foremen's material reports, distribution sheets and authorizations of expenditures is a matter in which the Accounting Department is as much interested as the Maintenance of Way Department, for the reason that these forms and reports are the foundation of the entire maintenance of way accounting structure, that it would be advisable for this Association to join with the American Railway Accounting Officers' Association in the development of a set of forms, to be recommended by each association, which would be generally adopted by railways.

SUBJECT NO. 2.

The Committee carefully discussed the report made last year with Mr. McVeigh, the representative sent by the Storekeepers' Association, and we believe that the conclusions which we have reached will meet with the approval of Mr. McVeigh, and that there is a strong probability that they will be approved by the Storekeepers' Association. Discussions were confined to the conclusions approved by the Association at the annual meeting in 1912, which were under the following headings:

(A) Standardization.
(B) Classification of Material.
(C) Stock Account.
(D) Distribution.
(E) Organization.

(A) Standardization.—No change is recommended for this heading.

(B) Classification of Material.—The Committee recommends that the details of classifications should conform to those adopted by the Railway Storekeepers' Association.

(C) Stock Account.—The conclusion reached last year is fundamental. The detailed methods of keeping the accounts may be varied to fit the individual condition. Stock accounts can be kept, first, by ledger account; second, by card system, and third, by personal inspection and estimation.

(D) Distribution.—No change is recommended for this heading.

(E) Organization.—The essential elements are as follows:

(1) Location.—The store should be located as closely as possible to the point of greatest consumption so that the minimum force will be required, and that the delay to material between the store and its destination may be reduced to a minimum. Usually this is at a point where equipment is maintained.

(2) Force.—The force required is dependent almost entirely on the character and volume of material issued and on local conditions. As the prompt and efficient handling of material and tools has a vital effect on the economical operation and maintenance of the railway, the force in the storeroom should be large enough to bring about this result.

(3) Position in Organization.—The consumption of supplies being greatest in maintenance of way and equipment, the Storekeeper should be closely associated with the heads of these departments. It is the opinion of the Committee that this can best be accomplished by having the Storekeeper, Engineer Maintenance of Way and the Master Mechanic report to the same officer. In a divisional organization this would place the Division Storekeeper under the Superintendent and the General Storekeeper under the General Manager or Vice-President in charge of operation.

(4) Mechanical Equipment.—Cost of unloading, storing and loading material depends solely upon the volume of business done by each store, and such appliances as will reduce this cost to a minimum are recommended.

(5) Plan.—A typical layout of a store is herewith presented, which can be expanded or reduced as the situation demands.

SUBJECT NO. 3.

The Interstate Commerce Commission, in their Classification of Operating Expenses, which became effective July 1, 1907, included in the maintenance of way accounts primary Account No. 6—Roadway and Track. This account includes about one-third of the total charges for material and labor in the maintenance of way and structures accounts. This account includes practically all of the labor performed by section and extra gangs chargeable to the maintenance of way and structures operating expenses, and it seems desirable to provide subdivisions of this primary account in order to analyze operating expenses and assist in securing uniformity of labor costs.

A brief outline of the reasons for recommending the proposed subaccounts is as follows:

Sub-Account A—Track Maintenance:

Under this caption is included all labor necessary to maintain good line and surface of track, except for the application of material. In other words, if the material and drainage conditions are good, but the track is in poor line and surface, the labor necessary to place the track

in good condition will be charged to this sub-account. Also, if it is necessary to temporarily reduce expenses, the available force should be used on line and surface work so far as possible.

Sub-Account B—Applying Track Materials:

Applying Track Materials is subdivided into

(B-1) Applying Ballast;
(B-2) Applying Ties;
(B-3) Applying Rails;
(B-4) Applying Other Track Material.

These sub-accounts will furnish as much detail as is practicable for convenience in comparing labor costs.

Sub-Account C—Cutting Weeds and General Cleaning:

This sub-account includes work which is less important than some of the other items, and the amount expended is largely dependent upon keeping the property in presentable condition rather than for reasons affecting safety or economy.

Sub-Account D—Ditching and Bank Widening:

This sub-account includes the most important element in providing good track. Frequently the material removed from cuts is used in widening embankments and, therefore, ditching and bank widening are logically included in the same sub-account.

Sub-Account E—Changing Alinement and Grades:

Under this caption is included the operating expenses resulting from abondoning the present alinement on account of reduction of grades or curvature, and it is necessary to separate this from the other expenses which more directly affect the economical maintenance of the property.

Sub-Account F—Flood Damage:

This sub-account includes the cost of repairing damage to the roadbed and track caused by unusual conditions, such as cloudbursts, floods, etc. It is necessary to separate this class of expenditures from the ordinary maintenance work in order that the latter may truly reflect the average expenses in maintaining the property. This sub-account also furnishes the basis for investigations to determine the amount which may be profitably expended to eliminate future damage.

Sub-Account G—Bank Protection:

Under this caption is included expenses necessary to protect the roadbed and track from slides, washouts and other unusual damage to the property.

Sub-Account H—Filling:

This sub-account provides for the expense of filling bridges.

Sub-Account I—Other Care of Roadway and Track:

This sub-account is intended to include the cost of trackwalkers, watchmen and other expenses not specifically provided for in the other sub-accounts.

It is the opinion of your Committee that the subdivisions of the Interstate Commerce Commission Classification, Account No. 6, of Operating Expenses, will be of assistance in securing uniformity of labor costs, but in order to obtain the greatest efficiency and most economical results additional information must be obtained and action taken.

Some of the most important elements in securing uniformity of labor costs and efficiency in handling work are as follows:

(1) Adoption of proper method for doing the various kinds of work under usual conditions. Efficiency in the various kinds of work performed in the Maintenance of Way Department has received very little study up to the present time, and it is safe to say that practically the same methods are being followed to-day that have been in use for a great many years. As an illustration, there are probably as many methods employed by section foremen in putting in ties under the same conditions as there are foremen doing this work, and by making a careful study of the elements entering into each operation the best method employed by each foreman may be combined to produce an approved practice for the various items of work under the most usual conditions.

(2) Economical distribution of material so as to reduce the amount of labor necessary in applying.

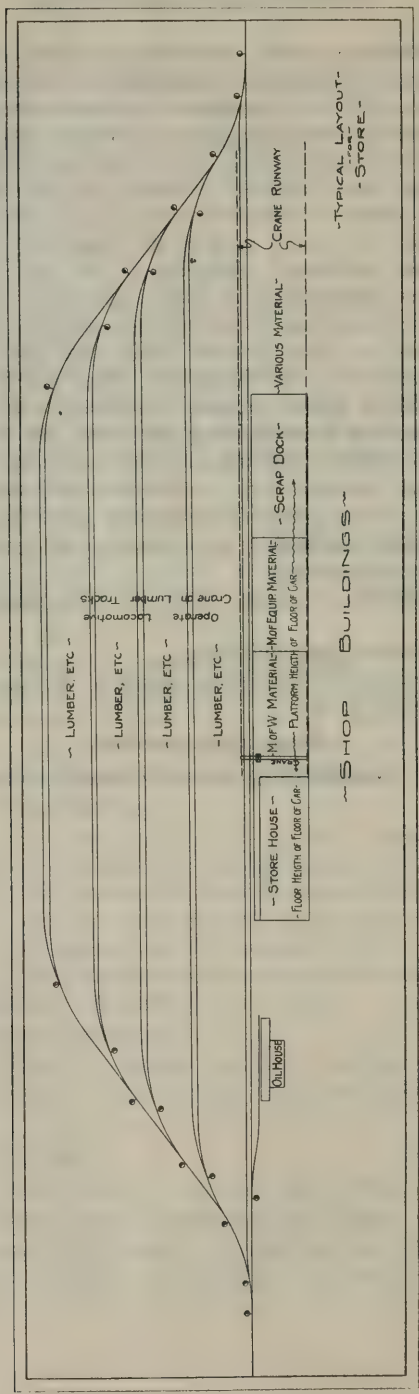
(3) The selection of proper tools and their maintenance in good condition.

(4) Organization and supervision.

(5) The selection of the proper season of the year for performing the various kinds of work.

Respectfully submitted,

COMMITTEE ON RECORDS AND ACCOUNTS.


Typical Layout
Store
Shop Buildings
Store House
Floor Height of Floor of Car
M. of W. Material
Platform Height
Mof Equip Material
Floor of Car
Scrap Dock
Various Material
Crane Runway
Lumber, etc.
Lumber, etc.
Lumber, etc.
Lumber, etc.
Operate Locomotive Crane on Lumber Tracks
Oil House

DISCUSSIONS

DISCUSSION ON RULES AND ORGANIZATION.

(For Report, see pp. 65-70.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RULES AND ORGANIZATION.

W. G. Atwood.
Hadley Baldwin.
W. McC. Bond.
Geo. H. Bremner.
G. D. Brooke.
W. M. Camp.
J. L. Campbell.
C. E. Denney.
L. A. Downs.
L. C. Fritch.
E. A. Hadley.
J. R. Leighty.
C. E. Lindsay.
Hunter McDonald.
J. C. Mock.
A. Montzheimer.
G. A. Mountain.
F. P. Patenall.
H. T. Porter.
S. S. Roberts.
L. S. Rose.
H. R. Safford.
O. E. Selby.
A. G. Shaver.
H. J. Slifer.
C. H. Spencer.
C. H. Stein.
F. S. Stevens.
Thos. S. Stevens.
Earl Stimson.
John G. Sullivan.
Albert Swartz.
Edwin F. Wendt.
H. S. Wilgus.

The President:—In the absence of the Chairman of the Committee, Mr. Jos. O. Osgood, the report of the Committee on Rules and Organization will be presented by the Vice-Chairman, Mr. G. D. Brooke.

Mr. G. D. Brooke (Baltimore & Ohio):—The subjects assigned to the Committee on Rules and Organization are as follows:

"(1) The compilation of rules for the government of maintenance of way employés, and

"(2) The formulation of rules in the nature of specifications or instructions regarding the conduct of work, making use of the recommendations of the various Committees dealing with these subjects and with the best practice of Railway Companies as embodied in their books of rules."

A meeting of the Committee was held in New York, in November, 1912, the Chairman and five members being in attendance, the rest of the members being represented by correspondence.

Working under the first instruction for the current year, the Committee recommends that Rule No. 8, under "Track Supervisors," "Track Foremen," "Supervisors of Structures," "Bridge and Building Foremen," "Signal Supervisors," and "Signal Foremen," be changed to read as follows:

"They shall conform to the prescribed standards, plans and specifications in the execution of the work under their charge."

We also recommend that two new rules (12) and (13) be added under General Notice.

Under the second instruction, the Committee recommends the addition of a number of rules which are given on pp. 66 to 69 of the Bulletin. Concerning these rules a number of suggestions have been made, some by correspondence and otherwise, and they have all proved ac-

ceptable to the Committee and will be mentioned as the report is proceeded with. If there is no objection, I would suggest that the rules be read, and if there are no exceptions on the part of the members, that they be accepted.

The President:—If there is no objection, the usual custom will be followed, and the Secretary will read the changes or proposed new rules, and the paragraphs as read will be considered adopted, unless objection is made.

Mr. C. E. Lindsay (New York Central & Hudson River):—I believe this Association should take great care in the preparation of these rules, as to the language that is used. Rule 8 is an example of what I have in mind. I believe the use of the word "they" at the beginning of the rule is unfortunate. I believe that all rules should start off with the title of the employé to which the rule relates in each case. Each rule should be complete in itself. Then take the first part of that rule and substitute the words "track supervisors" and then the rule would read: "Track Supervisors shall conform to the prescribed standards, plans and specifications." Let us stop at "specifications," and we are led to ask, "What specifications are intended here, to which a track supervisor shall conform?" I think the rule should read as follows:

"Track Supervisors shall do their work in accordance with the standard plans and specifications." I move that substitution.

Mr. Brooke:—In regard to the word "they" at the beginning of the rule, I will say that this rule follows a number of rules which have already been adopted by the Association, and the idea is to put the rules in similar language. This rule will be under a heading, "Rules Governing Track Supervisors" or "Rules Governing Track Foremen," and the word "they" will refer to the heading at the top of the series of rules. Now if this rule is changed, it would ultimately bring about the change of all the rules adopted heretofore, which are of a similar nature. It would also cause the use of two words, "Track Supervisors," or "Track Foremen" where one pronoun will answer just as well. The reading of the rule as it now stands is very much in accordance with the language that was adopted by the Association last year, which appears just above the proposed rule, the only change being the insertion of the word "specifications," which is put in to make the rule conform to other rules which have been adopted. I hope the motion will not carry.

Mr. Lindsay:—Our foremen are not grammarians, and they cannot always associate the pronoun with the proper noun, and the use of the words "Track Supervisors" or "Track Foremen" makes it direct and positive, and leaves no doubt in their minds as to what is meant.

Mr. L. A. Downs (Illinois Central):—It seems to me, inasmuch as there is a general heading to these rules, such as Supervisors, and then another heading for Foremen, that it is good form to use the word "they." Similar rules have been printed in the Manual and passed by the Association, and we seemed to think that it was proper then and I think it is proper now. I am opposed to the motion.

Mr. Earl Stimson (Baltimore & Ohio):—I agree with the Vice-Chairman of the Committee that the use of the pronoun "they" is proper; however, I think the rule should read, "They shall conform to the prescribed standard plans and specifications, etc." This is for the reason that the standards are prescribed through the medium of the plans and specifications. I therefore think this would be plainer than the wording as printed in the proposed rules.

Mr. L. C. Fritch (Chicago Great Western):—I agree with the Committee—the wording follows the general practice in all books of rules. The caption shows to whom the rules refer, and the use of the pronoun is much shorter than to repeat names of the persons to whom the rule applies. It also seems that the rule as promulgated by the Committee covers every condition. It covers standards alone, and it covers plans and specifications, and I am in favor of the Committee's recommendation as it is.

The President:—If there are no further objections to the rule as read, the Secretary will please proceed.

The Secretary:—Under "Track Foremen," change rule No. 17 to be No. 18.

Insert a rule under "Track Supervisers" to be No. 17 and under "Track Foremen" to be No. 19 to read as follows:

"Any action proposed by County, Township, Municipal or other authority, which will in any way affect the Company, shall be reported immediately to the ..... (Title) ....."

Mr. L. C. Fritch:—I would suggest that the State be included in that. It covers every subdivision except the State. Very often employés to whom this is directed have information in regard to any State action taken.

The President:—The Committee accepts that modification, and will insert the word "State" before "County."

Mr. H. J. Slifer (Consulting Civil Engineer):—This covers all the authorities, but it often happens that private persons may encroach on the railroad's property, and there is nothing to cover it in the rule, so it becomes an awkward situation. It seems to me we ought to say "any public authority or private person."

Mr. Brooke:—It is usually pretty hard to tell what a private individual or corporation proposes to do. This rule refers to any proposed public improvements concerning which the Supervisor or Track Foreman could secure information.

Mr. Slifer:—Take it out on the prairies of Iowa. A farmer will frequently drain his farm—I have known of cases not only in Iowa, but Illinois and Wisconsin and other Western States, where they deliberately put the tile drain underneath the track and the Track Foreman reports nothing about it.

Mr. Brooke:—I think there is a rule requiring all encroachments reported, which would cover that case.

The President:—Unless there are other objections, we will proceed, the rule standing with one insertion, "State" before "County."

The Secretary:—"Insert under General Notice rules to be No. 12 and No. 13 and reading as follows:

"(12) The use of intoxicants by employés while on duty is prohibited. Their use, or the frequenting of places where they are sold, is sufficient cause for dismissal.

"(13) Employés subject to emergency call shall notify their immediate superior officer and the Division Superintendent of any change in address, whether temporary or permanent."

Mr. L. A. Downs:—I would suggest that instead of the words "Division Superintendent," that that be left blank, because as a matter of fact we do not do that on our road, but usually report to the Chief Dispatcher or someone who is on duty. My suggestion is that we leave it blank.

Mr. Lindsay:—The rule seems to require the notification as to changes only. Unless there is some other rule to notify them *primarily* of their address, this rule should require these men to keep the officials notified of their address, whether permanent or temporary, and I suggest the substitution of the sentence, "Employés subject to emergency call shall keep their immediate superior officer, or Division Superintendent, advised of their address whether temporary or permanent."

The President:—The Committee hardly think that is a necessary change, because the men are supposed to have on record their permanent address and this presupposes a change.

Mr. Slifer:—As I understand the intent of this rule, it is that the employé is supposed to keep his superiors advised of his address or of his location. If he goes away to the other end of his division, a change in his address or his location is supposed to be sent to the office.

Mr. Brooke:—This was intended to cover the change of address, not his location at all times during the 24 hours.

Mr. Slifer:—It seems to me that that question of location is a very important one.

Mr. Brooke:—I think it is a very important one for certain classes of officers, but not so much for a Section Foreman, because, unless he has authority to be away, he is supposed to be on his section. For a Supervisor I think it is important, but the idea of the Committee was that that should be covered by special instructions.

The Secretary:—"27. Tie-plates must be used wherever ties wear out faster than they fail by ordinary decay. They must be put on so as to get a full and level bearing on the tie and against the rail."

Mr. L. C. Fritch:—I suggest that the word "should" be substituted for the word "must."

The President:—The Committee will accept that.

Mr. Earl Stimson:—One of the important functions of tie-plates is the maintenance of gage. I therefore move that this be amended by adding "and where necessary for the proper maintenance of gage."

Mr. Brooke:—The Committee will accept that.

Mr. L. A. Downs:—Several years ago, in going over a similar report, it was decided that little changes in words would not be considered; that the Committee on Publications would do that, but two years ago we had an extensive discussion on tie-plates, as to where they would be used. I recall Mr. Byers, of the Missouri Pacific, offered a substitute that seemed to be just the thing. His substitute was "that when the mechanical wear exceeded the decay, tie-plates would be used." Everybody thought that was just right and it was adopted. It seems to me it would be a good substitute for rule 27 and very much better language to be used, to say, instead of "whenever ties wear out faster than they fail by ordinary decay," to use the sentence, "when the mechanical wear exceeds the decay, tie-plates should be used."

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—I would like to ask where the Committee got this rule.

Mr. Brooke:—Why, the Committee formulated the rule.

Mr. Rose:—It reads to me very much like a rule that was promulgated by the Track Committee.

Mr. Brooke:—The note just above it states, "In preparing these rules the specifications have been taken wherever possible from the approved recommendations of the other committees of the Association." I do not remember whether the wording is just the same, but wherever possible the conclusions that have been reached by the other committees, and adopted, have been made use of.

Mr. Rose:—That is what I am coming to. If you change this rule you are going back into all of the work of the Association. I think the rule ought to stand if that is where it came from.

Mr. Brooke:—I might state that the Committee had in mind the mere adaptation of the principles contained in the specifications which had been formulated by the Committee on Track. It did make an effort to adapt the language so that it would be understood by the Track Supervisors and Track Foremen, and the Committee was very careful not to change any principles.

Mr. F. P. Patenall (Baltimore & Ohio):—Can the Chairman of the Committee tell us what rule 27 is supposed to supersede in the Manual?

Mr. Brooke:—It is not supposed to supersede any rule whatever.

Mr. L. C. Fritch:—In the Manual, page 64, under "Track," is rule 5, reading as follows:

"Tie-plates should be applied in all cases where greater economy in maintenance is secured by their use than in depending on the life of the tie limited by rail wear."

The President:—The Chair thinks you are quoting from an old Manual.

Mr. L. C. Fritch:—Pardon me.

Mr. C. H. Stein (Central of New Jersey):—Mr. Chairman, I had that very rule in mind when Mr. Fritch got up. It is found on page 115 of the 1911 Manual. It reads: "Tie-plates are recommended in all

cases where economy in maintenance will result from their use." It seems to me that that specification would fully cover this proposed rule 27, in the report of the Committee on Rules and Organization, and that if it was substituted in this Committee report it would fully cover the case.

Mr. Brooke:—The only reason the Committee had for changing that was that it thought the language used in this present rule No. 27 was better adapted to the understanding of a Track Foreman.

Mr. Geo. H. Bremner (Chicago, Burlington & Quincy):—Is it the province of this Committee to go into the details of when tie-plates shall be used? Is it not their province rather to say how they shall be used and how they shall be put on? Are not these rules for the governing of the section men and ordinary track employés? This Commitee should not go into details of when tie-plates shall be used.

Mr. L. A. Downs:—I offer a substitute, to say that "tie-plates are used" instead of the words "must be" as a descriptive proposition. "Tie-plates are used whenever ties wear out faster than by ordinary decay."

Mr. Brooke:—The Committee accepts that.

Mr. Earl Stimson:—I understand now that your acceptance of Mr. Downs' suggestion replaces entirely the rule you propose, with the amendment of mine that you accepted?

The President:—The way it stands now is that tie-plates shall be used wherever ties wear out faster than they fail by ordinary decay and where necessary for the maintenance of gage they must be put on so as to get a full and level bearing on the tie and against the rail. The last motion is that nothing be in this rule except the first sentence, "Tie-plates are used wherever ties wear out faster than they fail by ordinary decay."

Mr. L. A. Downs:—My suggestion was to use the word "are" instead of the words "must be," accepting the full rule as the Committee has it, with the substitute by Mr. Stimson that was accepted by the Committee.

Mr. W. M. Camp (Railway and Engineering Review):—I would suggest that the word "should" would be more satisfactory in that place. That makes it a recommendation. The word "must" makes it mandatory. Is my suggestion acceptable to the Committee?

The President:—The Committee originally accepted that. They are now inclined to accept "are" as descriptive only.

Mr. Hadley Baldwin (Cleveland, Cincinnati, Chicago & St. Louis):—I believe tie-plates are used practically only on the expressed authority of the Supervisor. It seems to me that the first part of the rule may be left out.

Mr. L. C. Fritch:—I agree with Mr. Baldwin's remarks, except that I would suggest the first part be left in and let it read, "tie-plates shall be used in accordance with prescribed practice," and the remainder be added as given.

Mr. Lindsay:—The use of the words "full and level" is unfortunate. The bearing of tie-plates is not always "level" on curves. I believe the

words "full and level" should be omitted. I believe the rule would be better if it read, "Must be put on so as to give a full bearing on the tie and for the rail."

Mr. Slifer:—I do not believe it would do this subject any harm if we referred the paragraph back to the Committee and asked them to make a modified rule. Therefore I make that motion.

Mr. Earl Stimson:—I do not see anything to be gained by referring it back to the Committee. It is a very simple proposition and is fully covered. Tie-plates are used to prevent the mechanical wear of the tie and to maintain gage, and that is clearly stated. This is a rule for the guidance of the foreman and other maintenance of way employés. If we are going to have any of these rules at all, we ought to begin with this one and adopt it. If we bar out this one for the reasons given, we will bar out every other rule proposed.

The President:—The Chair understands you accept what the Committee has agreed to accept?

Mr. Earl Stimson:—"Should" is the word that ought to be used. "Should be used" implies a recommendation as to the standard practice. "Are used" is merely a statement of existing practice.

Mr. L. C. Fritch:—We have been scrapping over this for fifteen minutes now. If we refer it back to the Committee, next year we will talk about it for twenty minutes more. I think we had better settle it to-day instead of postponing it.

Mr. Earl Stimson:—I call for the question on the original motion.

The President:—A motion has been made and seconded that this rule be referred back to the Committee for further study.

(The motion was lost.)

The President:—The Chair thinks we can consider, in view of the acceptance by the Committee, that we have before us this wording: "Tie-plates are used wherever ties wear out faster than they fail by ordinary decay, and where necessary to maintain the gage they must be put on so as to get a full and level bearing on the tie and against the rail."

Mr. Brooke:—The Committee will change the word "wherever" to "where." That will eliminate the objection that the tie-plates are not used on all roads.

Mr. Slifer:—I move to strike out the first clause.

Mr. C. H. Spencer (Washington Terminal Company):—I move, instead of the word "are" the word "should" be used. It will then read "tie-plates should be used wherever ties wear out faster than they fail by ordinary decay."

The President:—That is out of order just now. The motion before the house is with reference to the substitution of the word "are."

(The motion was lost.)

Mr. J. L. Campbell (El Paso Southwestern):—I move that this rule be amended to read as follows: "When tie-plates are used, they shall be applied so as to secure a full bearing upon the tie and for the rail."

(Motion carried.)

The Secretary:—"28. Perfect gage is one of the essential features of good track; gage kinks are as detrimental as low joints."

Mr. Rose:—I move that the second half of that paragraph be cut out, referring to "gage kinks are as detrimental as low joints." It depends on what a gage kink is. I do not believe you can prove that a gage kink is more detrimental than a low joint.

(Motion carried.)

Mr. S. S. Roberts (Consulting Engineer):—As it now stands, the rule looks more like an axiom. It simply makes a statement that a perfect gage is one of the essential features of good track.

Mr. Albert Swartz (Toledo Railways):—We might say, "Perfect gage is one of the essential features of good track and must be maintained." Then we would have a rule.

Mr. Brooke:—I might say that was taken from the rule book of one of the very prominent railroads, and there was some discussion in the Committee as to the propriety of the rule, but the Committee thought that it outlined a very good practice and that was the reason for its adoption.

The President:—The Committee is willing to accept the suggestion of Mr. Swartz, and if there is no further discussion the rule will stand in that form.

The Secretary:—"29. The standard gage is 4′ 8½″. Curves eight degrees (8°) and under should be standard gage. Gage should be widened one-eighth inch (⅛″) for each two degrees (2°), or fraction thereof, over eight degrees (8°) to a maximum of four feet nine and one-quarter inches (4′ 9¼″) for tracks of standard gage. Gage, including widening due to wear, should never exceed four feet nine and one-half inches (4′ 9½″)."

Mr. Lindsay:—I suggest substituting six degrees for eight degrees, and $\frac{1}{16}$-in. for each degree, instead of ⅛-in. for each two degrees.

Mr. Rose:—I want to say that this rule is practically copied out of the Manual, and was submitted by the Track Committee, and Mr. Lindsay helped to get it up.

The Secretary:—"30. The installation of frogs upon the inside of curves is to be avoided wherever practicable; where this is unavoidable the gage of the track at the frog should be standard."

Mr. H. R. Safford (Grand Trunk):—Is this a proper rule to put under instructions to the Section Foremen on the theory that the location of the switch is a matter which is not left to the judgment of the Section Foremen? It is always prescribed by the higher officer, generally the Engineer in charge of maintenance on the division. Therefore, it seems to me it hardly comes in in connection with rules as applied to Section Foremen.

Mr. Brooke:—There is a suggestion regarding this paragraph as follows: "The installation of frogs on curves is to be avoided wherever practicable," and the Committee had accepted that suggestion in substitution of the one printed.

Mr. Safford:—I do not think that quite answers the point I had in mind. I do not think it is a proper rule under instructions to the Section Foremen. It is not recognized as proper practice. The only point I had in mind was that this was not a matter for the Section Foreman to determine, and for the purpose of getting some expression, I move that the rule be eliminated.

Mr. Brooke:—These instructions were not intended particularly for the Section Foremen. They are rules for the Supervisors of Track, Supervisors of Buildings and Bridges, Track Foremen, and Foremen of Bridges and Buildings, as are similar instructions of a more general nature. Of course, it was very hard to differentiate between the rules that should be given to the foremen and those which should not, and I think this rule would probably apply to Supervisors, to a certain extent.

Mr. Safford:—I do not believe we will leave the location of main track switches to them. The location of switches is generally approved by the division officers. If I understand the intent of these rules, we are trying to describe detailed rules of practice.

Mr. L. A. Downs:—We are losing sight of the last part of the rule; that is where the rule really comes in. As a matter of fact, there are frogs on the inside of curves, and if there are frogs on the inside of curves, there should be some rule governing them. The latter part of this rule says, "Where this is unavoidable, the gage of the track at the frog should be standard." That is really the rule; the first part is descriptive matter.

Mr. Safford:—I agree to this extent, that the second portion of the paragraph really is the rule. If the rule should be formulated to specify what shall be done when that condition is met with, that will meet the matter I had in hand.

Mr. L. A. Downs:—I will amend Mr. Safford's motion, that the rule be stricken out, by moving that the rule be amended to read as follows: "When frogs are installed in the inside of curves, the gage of track at the frog should be standard."

Mr. Swartz:—Why not strike out the word "inside?"

Mr. L. A. Downs:—I will accept that.

Mr. Lindsay:—There is no necessity for maintaining standard gage when the frog is on the outside of curve, because the guard rail is moved to its correct distance from the frog point, but when you go around a curve with the frogs on the inside, the flangeway of the frog is fixed and you cannot change it, and that pulls the wheels down hill, causing a hard blow by the wheel on the guard rail which injures both.

Mr. F. S. Stevens (Philadelphia & Reading):—It appears to me that this proposed change in reading is unimportant, as it is practically the same as appears in the Manual, the matter having been adopted in 1910. The reading of the Manual is as follows: "The installation of frogs upon the inside of curves is to be avoided wherever practicable, but where same is unavoidable, the above rule should be modified in order to make the gage of the track at the frog standard." The difference is so little

that it does not appear to me to be necessary to make a change that will make it necessary to modify the language in the Manual. It is unimportant and the language of the Manual should be allowed to stand.

Mr. Thos. S. Stevens (Santa Fe):—It occurs to me that nothing has been said about the probable purpose of the Committee in preparing these rules. I believe that the standard prescribed by them is good, and that is a question I am not capable of passing on; the widest publicity we can give to it is desirable. It is just as well to have the Section Foreman know what the standard is, as the Division Engineer, with the idea that perhaps some time or other the Section Foreman may be able to check up the Division Engineer in some possible error he has been led into by mistake. I believe there is an underlying principle involved here, which this Association should discuss and that is the general advisability of including this kind of standardization in our book of maintenance rules.

The President:—The motion before the house is to have this rule changed to read as follows: "When frogs are installed on the inside of curves the gage of track at the frog should be standard."

(The motion was lost.)

The President:—The other motion before us is to strike out the rule entirely, and the Committee think as rule 40 has been inserted, and as we have another rule in the Manual, it would be all right to do this, and they have accepted it. Will you have the rule omitted entirely?

(A vote being taken, it was not agreed to.)

Mr. J. L. Campbell:—It seems to me this rule in some form should be one of the rules in reference to the track gage. The point that we want to convey is not to decide whether or not the frog should go in, but to determine how it should be installed and how the gage should be maintained. It seems to me if we should say, "when the frog is installed upon a curve, the gage of the track at the frog shall be standard," would be an instruction to the Section Foreman or the Track Supervisor, and would be a safe rule to follow.

Mr. Rose:—I move the adoption of the rule as it stands.

(Motion carried.)

The Secretary:—"31. On all curves the amount of superelevation to be given to the outer rail and the proper easement to be provided at the ends shall conform to the standards for 'Track' as prescribed by the American Railway Engineering Association and published in the Manual, edition of 1911."

Mr. Lindsay:—My understanding is that the American Railway Engineering Association does not prescribe standards, and this rule is wrong. Furthermore, the rule should not limit the matter to the Manual, edition of 1911, because we hope to publish other Manuals. I believe the wording of the rule is unfortunate.

Mr. C. H. Spencer:—I suggest, for uniformity of language in the rule, that the word "superelevation" be changed to "elevation." Page

85, in the Manual, under definitions, uses the word "elevation." The word "superelevation" is not used in this connection.

Mr. Slifer:—When I read this rule and began to think that the rule was intended as an instruction to Section Foremen, I thought we were going too far. The elevations of a curve should follow certain stakes provided by the Engineer, and to have a Section Foreman follow certain rules and regulations of the American Railway Engineering Association is hardly a correct procedure. I hardly think this matter belongs in this book of rules. I move that it be stricken out.

Mr. Earl Stimson:—It might be well to advise the assembly that these are not rules for Section Foremen, but rules for all of our employés.

Mr. Patenall:—Before action is taken on the motion, I suggest that the Chairman of the Committee tell us why the Committee formulated this rule.

Mr. Brooke:—The Committee on Track, I think, has formulated, and the Association has adopted, a table of elevations for different degrees of curve, and this was intended to put the matter in the hands of Supervisors and Foremen somewhat in the shape of instructions to them. The reason the language of the rule is printed as it is was to prevent the necessity of reprinting that part of the report of the Committee on Track as it appears in the Manual.

Mr. Rose:—I hope this motion will not prevail. Not all the railroads have a large corps of Engineers to give stakes every time the Section Foreman wants to raise a low place in the track, and the Section Foreman must have some rule. If he does not have a rule prescribed by this Association or some other association of competent authority, he will have a rule of thumb, and I think it is best to get in some rule.

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis):—There must be some rule for superelevation of the outer rail. The reading of the rule under discussion is that Section Foremen and Track Supervisors shall comply with the rules of the American Railway Engineering Association Manual. This would make it necessary for each Section Foreman to have a copy of the Manual and be familiar with it. There is no question that each road will have among its standards rules for superelevation on curves at different degrees. We have said in rule 8 that the Section Foreman shall conform to the standards of the road. I would move to amend the motion to strike out the rule, by substituting for the words, "Shall conform to the standards for 'Track,' as prescribed by the American Railway Engineering Association," etc., "conform to the prescribed standards of the railroad."

Mr. Lindsay:—Before putting that motion, I would like to omit the last two lines of the rule after the word "standards" and have the rule read, "On all curves the amount of superelevation to be given to the outer rail, and the proper easement to be provided at the ends shall conform to the standards," and omit the balance of it.

Mr. Brooke:—The Committee will be glad to accept that, with a notation in parenthesis referring to the standards of this Association.

Mr. Rose:—These rules are for the guidance of different railroad companies, and I do not think we ought to lose sight of the fact that we ought to steer the railroad company in the right direction to find this table. If the railroad has rules and standards, these things will not be used, but if they are getting up a set of rules and want to get some elevation tables, we should tell them where they can secure these, and that should be provided.

(Motion carried.)

The Secretary:—"32. Switches must be placed in accordance with the standard plans and as located by the Engineer."

Mr. Lindsay:—The heading should be "Switches and Frogs."

The Secretary:—"33. Switches and frogs must be kept well lined and in good order. Particular care must be taken to maintain good surface at switches.

"34. Switches must be inspected frequently to see that they are in working order and that all nuts, bolts and other fastenings are in place and properly tightened. Broken or damaged parts must be renewed promptly."

Mr. L. A. Downs:—I suggest that the word "frequently" be changed to "daily."

Mr. Brooke:—I think there are some cases in which the switches should be inspected more frequently than daily. Take an interlocking plant where there are 200 or 300 trains a day, daily would hardly be often enough. There are other places where trains might not run on Sunday and it would not be necessary to inspect. I think that is a matter that should be covered by specific instructions.

Mr. Swartz:—I suggest in place of the words, "are in place and properly tightened," that we use the words, "are properly placed." I think that would take care of the tightening. They are not in place unless they are properly tightened.

Mr. Lindsay:—Rules 33 and 34 cover the same ground and I suggest that they be combined into one rule reading: "Switches and Frogs must be inspected frequently and maintained in good line and surface. Bolts, nuts and other parts must be kept tight and in proper adjustment. Broken or damaged parts must be promptly renewed." I move the substitution of that for rules 33 and 34.

Mr. Earl Stimson:—I think we are to give instructions, too. I find it the best practice to make the rule as simple and concise as possible, and have one instruction cover one item only. Rule 33 covers general maintenance and rule 34 covers inspection. It goes into detail as to what this inspection should cover.

Mr. Thos. S. Stevens:—There is another thing the Association should take into account before they vote on the motion, and that is, eventually perhaps, the railroads will get out examination blanks on these rules, and when they do that it will be necessary to take the involved rule, as suggested by Mr. Lindsay, and divide it up into different parts, just as the Committee has done.

Mr. Hadley Baldwin:—Why is the word "frogs" omitted from rule 34?

Mr. H. S. Wilgus (Pittsburg, Shawmut & Northern):—There seems to be a little confusion perhaps in the terms used, Switches and Frogs. Sometimes switches might cover switch points, and would it not make it clearer if the heading "Switches" were replaced by the heading "Turnouts?"

Mr. Brooke:—That is unquestionably the case, but I think Mr. Lindsay suggested the word "Frogs." If there is no objection, the Committee is willing to substitute the word "Turnouts."

Mr. Lindsay:—That is agreeable.

Mr. Rose:—That will include the switchstand?

The President:—Yes.

Mr. H. S. Wilgus:—Then in rule 33, instead of saying "Switches and Frogs," would it not be better to say, "the turnout must be kept well lined," etc.?

Mr. Swartz:—If we are going to use the word "Turnout" as a caption, why not let us use the word "they." Turnouts include stands, points, and everything there is in it, and we use the word "they" all the way through in each of the other rules.

Mr. Rose:—"Turnout" will hardly take care of the crossing frog. These rules are intended to be definite. I think the rule should cover switches, frogs and switchstands, and be clearly defined.

Mr. Lindsay:—I prefer the terms "Switches and Frogs," because they are the weak points in the turnout, and those are the points which require particular inspection, and I think the term "Switches and Frogs" is definite. As Mr. Rose suggests, the word "Turnout" would not apply to a crossing frog where there were no switches.

Mr. C. E. Denney (Lake Shore):—Rule 34 is indefinite because of the word "frequently." A blank should be inserted so that the road could specify how often the switches on the entire line, or parts of it, should be inspected.

Mr. Brooke:—I think in adopting these rules they would have to be altered to a certain extent by all railroads, and I think the matter of frequent inspection is a good, broad principle, and for that reason I favor the word "frequently."

Mr. Camp:—I think Mr. Denney's suggestion a good one. This rule might be copied into some rule books, and the use of the word "frequently" is too indefinite. Would the Committee agree to provide for a blank space and then insert, in parenthesis, the words "how often"? thus to call the attention of any person making a copy of this rule that he should state how often the inspection of the frogs and switches must be made?

Mr. Selby:—I think the word "frequently" in this place is all right. It is not for this Association or for any other body to say just how frequently the switches and frogs should be inspected. Some of them need to be inspected more frequently than others, and the fact remains that

they should all be inspected frequently. The interpretation of the word "frequently" depends upon circumstances. There is a parallel use of an elastic term in the rule adopted by the American Railway Association, and practically all railroads, that the rear flagman of the train shall go back far enough to protect the train. That rule formerly was that he should go back a certain number of telegraph poles or a certain distance. The rule has been changed in recent years to read far enough to protect the train, and it leaves it to the judgment of the flagman. Here we have a similar rule, leaving the matter of the frequency of inspection to the judgment of the Section Foreman or Supervisor, or to be fixed by specific instructions from a higher official.

Mr. Denney:—The American Railway Association flagman rule is definite. It specifies doing a certain thing to accomplish a certain result. This rule, if inserted in the books as written, would have to be supplemented by instructions and weaken the rule. If it were written with a blank it would conform to many American Railway Association rules intended for the use of all roads, to be filled in as the road may determine.

Mr. Lindsay:—I like that word "frequently." The object of that word is to have inspection made often enough to insure the safety and good condition of the appliances, and that must be left largely to the judgment of the man who is in immediate charge of the work, and I believe he has intelligence enough to interpret the word "frequently" to do it often enough to insure safety.

Mr. Denney:—I move that the word "frequently" be eliminated, and a blank left in the rule with a note indicating the time is to be specified by the roads using the rules.

(Motion lost.)

Mr. W. G. Atwood (Lake Erie & Western):—I move the adoption of rule 34 in the form submitted by the Committee, the only change being the addition of the words "and frogs" in the heading.

(Motion carried.)

The Secretary:—"35. Switch points must fit closely and accurately to the stock rail, which must be bent to suit the angle of the switch. The bend in the stock rail shall be at such distance ahead of the switch point as will make the gage line continuous."

Mr. Hadley Baldwin:—I move that the word "frogs" be added in the rule.

Mr. S. S. Roberts:—I think the rule as it stands is rather indefinite. Inasmuch as most roads have a specified distance ahead of the switch point for bending the stock rail and as this Association has recommended certain distances ahead of the switch rail for this purpose, I move the rule should read, "Switch points must fit closely and accurately to the stock rail, and the stock rail must be bent in accordance with the standards." Then in parenthesis refer to the recommendations of the Track Committee of this Association.

Mr. J. C. Mock (Michigan Central):—I think movable frog points should be included.

Mr. S. S. Roberts:—Would not the movable frog point simply be in the nature of a switch—would not the motion cover the whole proposition?

(Motion carried.)

The Secretary:—"36. Lead rails in all turnouts must be curved with a rail bender before being laid."

Mr. Lindsay:—There is no necessity for curving with a rail bender in a No. 20 turnout, and I think the rule is entirely too comprehensive.

Mr. L. A. Downs:—I move that rule 36 be stricken out.

Mr. W. McC. Bond (Baltimore & Ohio):—Would it not be a good idea to make the rule read, "Rails for all short turnouts should be curved with the rail bender before being laid?"

Mr. Lindsay:—What is "short?"

Mr. Bond:—No. 3 frogs, 6's, anything like that.

(Motion carried.)

The Secretary:—"37. All main track switches leading to sidings or branch lines should be protected by switch connected derails."

Mr. Rose:—I move that rule be stricken out.

Mr. Earl Stimson:—I think you should take into consideration that is the accepted practice on many railroads where the switch is not connected up with the interlocking plants.

Mr. Rose:—It is the accepted practice on many roads not to do it. It depends if you need that protection.

The President:—There is a division of practice.

Mr. John G. Sullivan (Canadian Pacific):—There is another point about that. It might embarrass some of the roads in a legal way.

(Motion carried.)

The Secretary:—"38. Switch ties must be used for all permanent turnouts, crossovers and railroad crossings and placed as shown on the standard plans."

Mr. Swartz:—I do not believe it is good practice to use switch ties on railroad crossings. We generally use a heavier timber than switch ties.

Mr. Bremner:—I think this ought also to refer to the standards of the Track Committee.

The President:—The Committee will accept that and put a note referring again to the standard practice of this Association.

The Secretary:—"39. Frogs must be protected by guard rails, constructed and placed in accordance with standard plans. The tops of the guard rails must be level with the tops of the main rails and must be securely held in place.

"40. Guard rails must be so placed that the distance from the gage side of the head of the frog wing rail to the flangeway side of the guard rail shall be exactly four feet six and three quarters inches (4′ 6¾″) and great care must be taken to preserve this distance."

Mr. Brooke:—The Committee has a communication from Mr. A. K. Shurtleff, and he suggests this section should read as follows: "Guard

rails must be so placed that the gage distance from the frog point to the flangeway side of the guard rail shall be at least 4′ 6¾″, and the distance between flangeway sides of the wing rail and guard rail shall not exceed 4′ 5″. The Committee accepts this amended reading.

Mr. John G. Sullivan:—I think there is on practical case which has not been brought out in discussion of rule 30. That is where the frog is on the inside of a curve on a main line. In that particular case you can get some rough riding track if you spike the frog too close to the gage. What difference does it make what gage you have on the main line, if you get the gage of the turnout proper?

Mr. Rose:—It will tear your track to pieces.

(Rule 40 as amended was adopted.)

The Secretary:—"41. All signal posts, whistle posts, mile posts, signal targets, bridge and other standard signs must be kept plumb and in good condition.

"42. Whistle posts must be placed so as not to be obscured by fences or other signs."

Mr. Lindsay:—I think that should read, "All signal posts, whistle posts, etc., must be placed so that they will not be obscured."

The President:—The Committee accepts the change to section 41.

The Secretary:—"43. Tools must not be left standing within six feet (6′) of the nearest rail of the track on which a train is approaching."

Mr. Lindsay:—I think that should read, "Tools should not be left where they are liable to be struck by trains."

Mr. S. S. Roberts:—I think it is well to fix a distance, and I would say not less than six feet from the nearest rail.

Mr. Brooke:—The only question is, what period of time will it cover? There may be a train approaching and a man might stick up a bar within three feet of the track, and if a train was approaching he would have to move it, but if no train were approaching he could let it stand there.

Mr. Camp:—Mr. Lindsay's suggestion is a good one. If the tool were lying clear of the track, so that it could not be struck by a train, it would be all right. Six feet might put it over the edge of the bank or into a ditch. I think the phrase, "Tools must not be left where they are liable to be struck by trains," is a good wording to use.

Mr. Rose:—You might leave a track jack where it would clear the train, but be a menace to switchmen or trainmen walking around the track.

Mr. H. S. Wilgus:—I think the rule should stand as it is at present, for the reason that a tool might be left standing to clear an approaching train, but as the train approaches fall across the rail.

(The amendment was adopted.)

The Secretary:—"44. Road and street crossings must be constructed as shown on the standard plans and kept in good order.

"45. Particular care must be taken to remove as far as practicable all obstacles which obstruct the view of crossing signs and approaching trains."

Mr. Thos. S. Stevens:—May we have "fixed signals" added to that, "which obstruct the view of crossing signs or fixed signals," or would it be better to say, "signs and fixed signals from approaching trains?"

Mr. Rose:—I do not believe we could agree with Mr. Stevens' motion.

Mr. Lindsay:—The caption is "Road crossings," and for the particular use of the road crossings. Signals have no part in it.

Mr. Thos. S. Stevens:—All right, sir.

The Secretary:—"46. Flangeways must be kept clear of rubbish, snow, ice, and other obstructions; defective crossing planks must be repaired promptly."

Mr. Lindsay:—One of the most undesirable conditions about a road crossing is the liability of persons or animals to have their feet caught in the flangeways. I think we all have damage claims from that source. I would like to substitute for the latter part of that rule, omit all after "defective" and say, "special care must be taken to keep the crossings in such shape that the feet of persons or animals will not be caught in the flangeways."

Mr. Brooke:—If the crossing is constructed as provided by rule 44, as shown on the standard plans, and kept in good order, I think that ought to take care of that.

Mr. Lindsay:—My only object was to call particular attention to this particular source of danger.

(Rule 46 was adopted as read.)

The Secretary:—"47. Station platforms must be kept clean, free from rubbish, snow and ice, and in good order.

"48. Defective platforms must be promptly repaired or reported.

"49. Fences and gates along the right-of-way shall be kept in repair and all gates kept closed when they are not in actual use."

Mr. Lindsay:—I would like to ask if the words, "along the right-of-way" are necessary.

The President:—The Committee thinks they are necessary in referring to railroad fences and cattle-guards.

Mr. John G. Sullivan:—Is there any danger of shifting the responsibility from the farmer to the railway company? In some cases we have prosecuted farmers who have left the gates open.

Mr. G. A. Mountain (Canadian Railway Commission):—In reading this, I take it that it means instructions to the Supervisor and section-men to see that the gates are kept closed. In the Railway Act in the Dominion of Canada it is required that a farmer must close his gate immediately after using it. There is a danger with us in following this practice that the farmer will simply open it, drive through and leave it open. The idea in view in this case is that the Section Foreman would notify these men that if they leave the gate open, a penalty would be imposed upon them.

Mr. Brooke:—That was the intent of the Committee. There is some responsibility placed on the Section Foreman, to see that if a farmer

leaves a gate open it will be closed by the farmer. It is not necessary for the foreman to see that the gate is closed by his men.

Mr. Lindsay:—Will the Committee insert the words, "and see that all gates are kept closed?"

The President:—Does that not put the responsibility on the farmer?

Mr. John R. Leighty (Missouri Pacific):—I would suggest that we add to that rule as it stands, that a report be made to the proper officer of all gates which are habitually left open.

(Motion carried.)

The Secretary:—"50. Cattle-guards must be kept in repair and at all times free from dirt, rubbish and other obstructions.

"51. Track jacks must not be used between the rails of main tracks, except in unavoidable cases; the track must then be properly protected as in the case of other obstructions."

Mr. Lindsay:—That is a very important rule. The latter paragraph is rather indefinite. I suggest to substitute for it the words, "and then only under flag protection as per rule 53," so that the rule would read, "Track jacks must not be used between the rails of main tracks, except in unavoidable cases; and then only under flag protection, as per rule 53."

The President:—The Committee will accept that.

The Secretary:—"52. In case of impassable track, flagging is the first duty, and repairs must wait, if necessary, until signals have been placed."

Mr. Lindsay:—That rule is an important one also, and it seems to me it would read better if it said, "In case of impassable track, etc., repairs must not begin until signals have been displayed in accordance with rule 53."

Mr. Brooke:—I think we might start a flagman out and still begin work making repairs. This states that repairs must wait if necessary, but it is not always necessary that repairs wait.

Mr. Stein:—I do not think that Mr. Lindsay's point is very well taken. The very specification that the track is impassable signifies that repairs ought to be undertaken at once, and the signals be placed out as quickly as possible. In other words, the two acts should be coincident. I think the rule should stand as it is written.

Mr. Lindsay:—The rule says that flagging is the *first* duty; not a duty coincident with the commencement of work. The first thing a man does when he finds a piece of bad track is to put out his flag. When he has put out his flag, he can begin his work, but he must not begin work until he has put out his flag.

Mr. Stein:—I move the adoption of the rule as printed.

(Motion carried.)

The Secretary:—"53. The track must never be obstructed without first displaying stop signals not less than twenty (20) telegraph poles in each direction from the point of obstruction. Stop signals must be in the hands of reliable men. Flagmen must stop all trains and explain to the engineman the nature of the obstruction and its exact location."

Mr. Denney:—This Association cannot definitely specify flagging rules. For example, there are seventy telegraph poles to a mile. This requires placing flags out fifteen hundred feet. I move as an amendment the following: "The track must never be obstructed without first displaying stop signals ..... feet (..... rail lengths) in each direction from the point of obstruction." The road to fill in as desired for the entire line or division. All rules of this nature adopted by this Association should be written along these lines.

Mr. Slifer:—I would like to second the motion, but why not say, "Not less than (blank) telegraph poles?"

Mr. Denney:—Chiefly because telegraph poles vary, and rail lengths do not vary very much.

Mr. Thos. S. Stevens:—Would it not be better to say, "The track must not be obstructed without first displaying signals in accordance with rule 99 of the American Railway Association?"

Mr. Denney:—Replying to Mr. Stevens, I would say I believe the distance at which the signals should be placed on an engineman's operating division should be definitely spelled out by the road.

Mr. Rose:—I do not believe we can specify a certain distance even on an engineman's division. For instance, he might run up a two per cent. grade and run down a two per cent. grade. It would be foolish to put a flagman out under certain conditions. I do not believe we can determine how far a flagman should go. We might give him a minimum distance, but that should be short on a great many of the mountain railroads.

Mr. Hadley Baldwin:—I believe we should follow the American Railway Association in this respect. Its rule provides for the protection of trains and for the same kind of flagging that a trainman should use. This is one rule where we get pretty close to the transportation department. It seems to me we ought to be consistent.

Mr. H. T. Porter (Bessemer & Lake Erie):—I agree with Mr. Baldwin, that flagging is strictly a transportation problem, to protect trains. I think we should not only follow the spirit of the rules, but we should use the exact wording prescribed by the American Railway Association.

The President:—The Committee will accept the amendment.

Mr. Slifer:—There is a great deal of difference of opinion in regard to American Railway Association rule 99 among transportation men. I would like to know what rule 99 means. Rule 99 on the Chicago & North Western Railway reads one way, on the Chicago, Burlington & Quincy Railroad it reads another way. If you say this is rule 99 of the American Railway Association you are getting into deep water, because some roads have modified American Railway Association rule 99.

Mr. L. A. Downs:—I believe we should adopt rule 99 for the reason it was adopted by all the railroads of the country generally, and they modified it to suit themselves. I think we should follow the rules laid down by the American Railway Association, and this should be referred back and the rule rewritten next year. But I would like to make one

suggestion on this rule that is different as to track or bridge men and transportation men. We all know that it is a common error for track or bridge men to send out a flagman and "use the flag for everything until No. 2 comes." For instance, he expects, when he takes out a bridge, not to delay a high-grade passenger train; so he expects to get the track closed up. He will say, "go out and flag everything until No. 2 shows up, and then come in." We were very careful in making the maintenance of way rules of the Illinois Central, in which I took a very important part at the time, to embody in that specifically that the flagman must not come in until he is sent for. I make that as a suggestion, and then we can make a motion that the rule be rewritten next year.

Mr. Lindsay:—While I personally believe that the rule of the American Railway Association is all right, it is not satisfactory to some of our State governments. For instance, the State of Louisiana has amplified rule 99. I think that whatever rule may be adopted along the lines of the American Railway Association rule, we should add to it that flagging must be done by reliable men. It is not sufficient to say that the signals must be in the hands of reliable men, but the flagging must be done by reliable men.

The President:—The motion before the house is that the rule read as follows: "The track must never be obstructed without first displaying stop signals in general accord with rule 99 of the American Railway Association. Stop signals must be in the hands of reliable men. Flagmen must stop all trains, and explain to the engineman the nature of the obstruction and its exact location."

(Motion carried.)

The Secretary:—"54. When the track is not in condition for the passage of trains at the usual rate of speed, and this condition will continue over night or for the greater portion of a day, notice must be given immediately to the ..... In such notices the place of danger, its nature, and the speed at which trains may pass must be stated.

"In addition to sending this notice, slow (color) signals must be displayed. When repairs have been made the person making them must at once notify the ..... that the slow order may be recalled."

Mr. Lindsay:—Mr. President, I move the following: "When the track is not in condition for the passage of trains at the usual rate of speed, caution signals must be displayed immediately, and notice must be given to the ....., stating the place of danger, its position, and the speed at which trains may pass."

The President:—Nothing else in the rule at all?

Mr. Lindsay (continued):—"When repairs have been made, the person making them must promptly notify the ....., stating that the track is in condition for schedule speed."

Mr. Rose:—I believe Mr. Lindsay is right, except I believe here is one place where you can define the distance where precaution signals

shall be placed, and that can be made uniform. I would amend the motion to read, "at least one mile."

Mr. Denney:—I agree with the first part of Mr. Rose's remarks, but it should be blank. These rules are the basis of rules for railroads. On some divisions it may not be necessary to place the slow sign out one mile; on others half a mile would be sufficient, the distance depending on the speed and class of trains, grades, etc.

Mr. Thos. S. Stevens:—I do not believe the placing of caution signals fulfills the requirement. I believe we ought to go farther than that, and that all trains ought to be stopped by a flagman until it is definitely known that the slow order is issued, and the caution signal placed as a marker, to call the engineman's attention to the special place where the slow order is in effect.

Mr. Brooke:—I think the protection first is covered by rule 52, and the other is a detail which will cover that, so that you can take your flagman in and leave a stationary signal, with the additional precaution of a slow order, which will afford the necessary protection.

The President:—The matter before the convention is the revision of the rule according to Mr. Lindsay's reading, with a blank inserted instead of an exact distance: "When the track is not in condition for the passage of trains at the usual rate of speed, caution signals must be displayed immediately (blank) distance, and notice given to the (Title), and stating the place of danger, its nature, and the speed at which trains may pass. When repairs have been made, the person making them must promptly notify the (Title) in writing that the track is in condition for schedule speed."

Mr. Brooke:—I object to that for this reason: The caution signal may be placed before the slow order reaches the dispatcher or is placed in the hands of the engineman, and there is no one at the signal to tell him what the weakness consists of. My opinion is that the flagman should stay there until the slow order has been properly put.

Mr. Stevens:—The Chairman is right and the motion should be lost.

Mr. Lindsay:—On one first-class railroad that I know of the caution signal is specifically described in the book of rules of the operating department and gives the distance beyond a primary caution signal at which the track is obstructed; the engineman knows when he sees a yellow flag that there is a point a certain distance beyond that is marked, in accordance with the rule, by another flag, and that beyond that again there is another point at which he can resume speed. So the whole thing is covered. I believe the rule should be supplemented by the addition of a caution signal.

(By a rising vote the motion was lost.)

The President:—Now the motion is on the rule as read.

(The rule was adopted as read.)

The Secretary:—"55. The color, hand, flag, lamp and engine steam whistle signals, and the train markers prescribed by and published in the Standard Code of the American Railway Association shall be used.

(It is suggested that copies of the description and rules for the use of these signals, including diagrams, be inserted in books of rules governing maintenance of way employés.)

"56. All work which will obstruct the track must be done at such times as will interfere as little as practicable with the passage of trains."

"57. Except in case of emergency, no work that will obstruct the track shall be done during fogs or storms."

Mr. Lindsay:—Will the Committee eliminate the words, "case of" so that it will read, "except in emergency?"

The President:—The Committee will accept that amendment.

The Secretary:—"58. In obscure weather, or on heavy grades or curves, extraordinary care must be taken to make sure that the stop signals are out a sufficient distance in both directions to insure full protection."

Mr. Lindsay:—Would the Committee like to have that yellow light "out," or would the Committee like to have it "displayed?"

The President:—The Committee will accept that, "displayed at a proper distance."

The Secretary:—"59. While working under the protection of signals, great care shall be taken that the signals are intact and in their proper location and position. Disregard of signals shall be promptly reported to the .....

"60. In using signals on double track, each track must be considered as a single-track railroad upon which trains are likely to be run in either direction at any time."

Mr. Lindsay:—I would like to substitute for "signals on double track," "signals for multiple track," because we have four and six-track railroads, and I believe the rule would be better if it said, "Each main track shall be considered as a single-track railroad upon which trains are likely to run in either direction at any time, and signals must be displayed accordingly."

The President:—Do you offer that as a substitute?

Mr. Lindsay:—Yes.

The President:—The Committee will accept that.

The Secretary:—"61. Care must be exercised by foremen and other employés in the use of hand, push, motor and velocipede cars. In order to avoid accident, they must protect themselves with the proper signals, when the view is obstructed. On moving hand cars at least one man must face the rear to look out for approaching trains."

Mr. Lindsay:—There is an objection to that, "on moving hand cars at least one man must face the rear to look out for approaching trains." How about motor cars? "In order to avoid accident, they must be protected by signals, and when the view is obstructed, when practicable, one man on a motor car must face the rear to look out for approaching trains." It is not practicable on a velocipede, of course, with one man only operating it, to face both ways at the same time.

Mr. Earl Stimson:—When we modify a rule by saying "when practicable," it weakens it in the minds of most of us and renders it inoperative.

The President:—Mr. Lindsay objected to the words "hand car." I suppose that is all you wanted to cover?

Mr. Lindsay:—That when there is one man, he will look out in both directions. The point is that when there is more than one man, one man will look one way and the other watch the other way.

Mr. Earl Stimson:—Does Mr. Lindsay want to substitute that on all classes of cars that convey men over the road?

The President:—Yes. The Committee will not agree to that.

Mr. Thos. S. Stevens:—I move the acceptance of the rule as presented by the Committee.

(Motion carried.)

The Secretary:—"62. Such cars must be protected from the weather and when not in use must be locked."

Mr. Lindsay:—That rule, I imagine, is intended to mean that when the car is left alone over night; is that the idea?

Mr. Brooke:—When it is left out of sight of a gang during the day.

Mr. Lindsay:—When it is left alone?

Mr. Brooke:—Yes.

Mr. Lindsay:—Then I would move to amend by saying, when the car is left alone.

Mr. L. C. Fritch:—I would like to have the Committee add to that rule, "and must never be left standing on road crossings."

The President:—The Committee is not willing to accept Mr. Lindsay's motion. There are many crossings, they say, which are very convenient for leaving a car. The rule stands as accepted by the Committee, "Such cars must be protected from the weather and when left alone must be locked."

The Secretary:—"63. Cars must never be used or left on the main tracks or frogs unprotected. Loaded hand or push cars on the track are obstructions and must be protected by the proper signals."

Mr. Lindsay:—That last clause, requiring the protection of proper signals, "hand or push cars," eliminates the other cars, velocipede cars, and heavy motor cars. They are as dangerous and just as much an obstruction as a push car, and require as much protection.

Mr. L. C. Fritch:—I would like to have inserted in rule 63, after the word "sidings," "street or highway crossings."

Mr. Slifer:—I want to second that motion.

The President:—The Committee will accept that—"street or public crossings."

The Secretary:—"64. They must not be attached to trains. When following trains, or other moving cars, they must not run closer than ten (10) rail lengths."

Mr. Lindsay:—Mr. President, can we add to rule 64, "and must never be operated at excessive speed?"

Mr. Brooke:—I think that is covered properly by rule 61.

Mr. A. Montzheimer (Elgin, Joliet & Eastern):—I would like to see a clause added to rule 64 specifying that where two or more hand cars are moving over the road, they shall be kept at least ten rail lengths apart.

The President:—You have that in this rule.

The Secretary:—"65. They must be kept in good order and inspected frequently for loose bolts or other defects.

"66. Switches must not be thrown for such cars, unless loaded, and then only under the supervision of the foreman."

Mr. Lindsay:—Mr. President, I would like to confine that rule to main track switches, because in yards it is common practice, and always will be, to operate the switch by the man in charge of the car, without the foreman being there.

Mr. Brooke:—The Committee accepts that.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I would like to see rule 28 reverted to. There is an inconsistency between that and 29. I don't believe the Association ought to go on record with such an inconsistency as that. It says: "Perfect gage is one of the essential features of good track." I do not know of any road that maintains perfect gage. In rule 29 the words, down to the line next to the last, "gage including widening due to wear." If you are going to admit widening due to wear, which we will necessarily have to do, we cannot have perfect gage, and I move, therefore, that rule 28 be amended to read, "Uniform gage is essential to good track and must be maintained."

The President:—Do you want to make a motion to reconsider rule 28? It has already been passed.

Mr. Hunter McDonald:—I move that we reconsider rule 28, and that the substitute I offer be adopted.

(Motion carried.)

The President:—It is in order to reconsider rule 28, and the substitution proposed by Mr. McDonald is, "Uniform gage is essential to good track and must be maintained."

(Motion carried.)

Mr. A. G. Shaver (Rock Island):—I want to call attention to one thing I believe lacking in these rules for obstructed track, and that is the automatic block signal. In certain territory of some roads it is required that the Section Foreman assure himself that the signal is at "stop" while a rail or switch change is being made. It would be a good plan to include something of that kind in connnection with these rules.

The President:—The Committee will take that into consideration. It is now in order to adopt these rules as amended in their entirety.

(The rules, as amended, were adopted.)

Mr. Edwin F. Wendt (Pittsburgh & Lake Erie):—Mr. Chairman, before this Committee is dismissed, I wish to make a suggestion in connection with the work of next year. Much work has been done in connection with the question of rules, but very little attention has been

given to the subject of organization. In reading the final report of the Block Signal and Train Control Board of the United States Government, I was struck with the following statement, "As regards methods, it may be said that on the large majority of American railroads excellence of administration is nullified by faulty organization, magnification of individual function to the detriment of team work, and by an almost entire absence of a definite system of broad training of subordinates for higher duties." It seems to me that our Committee might well study the science of organization. Considerable literature has been developed in recent years respecting this question. The study of principles which underlie organization would be a proper work for this Association. I do not refer to those features of organization which give rise to so much discussion. Reference is made to the principles which underlie organization, and I think that this Committee should study what is called "the science of organization."

The President:—We will take that up in the Committee of the Directory, in assigning subjects for the coming year.

Mr. Lindsay:—I would like to ask that the Committee be instructed to prepare and submit to the Association next year a rule for the display of caution signals.

The President:—The Committee will take that into consideration as part of their instructions for next year. If there is nothing further, the Committee is relieved, with the thanks of the Association.

DISCUSSION ON SIGNALS AND INTERLOCKING.

(For Report, see pp. 71-80.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON SIGNALS AND INTERLOCKING.

A. H. RUDD. W. H. ELLIOTT.

The President:—The report of the Committee on Signals and Interlocking will be presented by the Chairman, Mr. A. H. Rudd.

Mr. A. H. Rudd (Pennsylvania Railroad):—Mr. President, this subject has been before this Association for six or seven years. It has been discussed and rediscussed. There have been minority reports. The reports have been turned back to the Committee, or rejected in this Association and in the Railway Signal Association. The present report is the unanimous report of the Committee. It was presented to the Railway Signal Association at their meeting in October, and sent to letter-ballot by unanimous vote. The result of that letter-ballot was 574 in favor of the report and 10 against it, two-thirds being necessary for its adoption; it has, therefore, been adopted by the Railway Signal Association. Under these circumstances we do not believe it is necessary to discuss it any further; in fact, further discussion would be detrimental. We believe it should be passed, adopted and sent to the Secretary of the American Railway Association as soon as possible. I believe the American Railway Association is working on a revision of the Standard Code, and that this may possibly assist them. At any rate, it will give them our sentiments. I would therefore move the adoption of the conclusion on page 75.

Mr. W. H. Elliott (New York Central):—I second the motion.

(Motion adopted unanimously.)

Mr. Rudd:—Subject No. 2. The report is printed on pp. 75 to 80, inclusive. This is presented as information, and it is pretty valuable information. Worth reading, but not here and now. Since receiving this information, Mr. Stevens, of the Santa Fe, advises me this morning that they had a track circuit 1,700 feet long. It was in a track coated with brine, a great many refrigerator cars passing over it; 150 of the zinc-treated ties were taken out and creosoted. Other ties were substituted, with the result that the voltage at the relay was increased 33 per cent. I move the acceptance of the report on No. 2 as information.

(Motion seconded and carried.)

Mr. Rudd:—Subject No. 3. Your Committee begs to state that this subject is being considered in connection with the report for 1914.

The President:—In receiving and acting upon this report we wish to thank this Committee very heartily. They have done a very large amount of work. The Chair thinks it is very gratifying to this Association to know that we have gotten over the difficulties and have a harmonized Committee, and, above all, that a matter so important has been unanimously adopted by this Association. Gentlemen, you are excused. (Applause.)

DISCUSSION ON IRON AND STEEL STRUCTURES.

(For Report, see pp. 81-96.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON IRON AND STEEL STRUCTURES.

A. W. Carpenter.	E. A. Frink.	H. A. Lloyd.
C. H. Cartlidge.	A. J. Himes.	A. F. Robinson.
Thos. Earle.	Geo. W. Kittredge.	O. E. Selby.
W. R. Edwards.	C. E. Lindsay.	P. L. Wolfel.

The President:—The report of the Committee on Iron and Steel Structures will be presented by the Chairman, Mr. A. J. Himes.

Mr. A. J. Himes (New York, Chicago & St. Louis):—The subjects assigned to this Committee for investigation during the past year were:

(1) Report on Rules for Instruction and Guidance of Inspectors in Mill, Shop and Field.

(2) Report on Methods of Protection of Iron and Steel Structures Against Corrosion.

(3) Study the Design of Built-up Columns, co-operating with other investigators and committees of other societies.

These subjects were assigned to sub-committees, only one of which has made a final report.

Committee meetings were held as follows: Buffalo, September 9, 1912, ten members present; Buffalo, February 28, 1913, six members present. In addition to the above a joint meeting with a committee of the Railway Signal Association was held at Buffalo, February 28, 1913, to consider joint action concerning the adaption of the designs of movable bridges to the signal and interlocking appliances required. The joint meeting was attended by six members of Committee XV and five members of the Railway Signal Association.

A final report on Rules for Instruction and Guidance of Inspectors in Mill, Shop and Field, accompanied by a general descriptive statement of qualities desired in an inspector, is given in Appendix A. The report, with the descriptive statement omitted, is recommended for adoption and publication in the Manual. Mr. Buel presents a minority report in Appendix B. Mr. Schneider desires that the report be referred back to the Committee for further study.

A progress report on Design of Built-up Columns is given in Appendix C.

Mr. C. D. Purdon, Chief Engineer of the St. Louis Southwestern Railway, in a letter dated October 19, 1912, requests that the Committee take under consideration a specification for phosphor bronze castings for use in bridge structures. Much valuable information relating to this subject has already been secured and a sub-committee has been appointed to compile the same and prepare it for publication in a Bulletin.

Mr. W. S. Bouton, Engineer of Bridges of the Baltimore & Ohio

Railroad, has called attention to the fact that "the recommendations adopted at the convention (March, 1912) with reference to third rail clearance diagrams conflicted with the clearance diagram for bridge structures, as shown in the Manual of 1911, page 404."

The matter was referred to Mr. George W. Kittredge, Chairman of the Committee on Electricity, who writes: "Referring to the attached correspondence, in regard to interference with the established bridge clearance diagram of the American Railway Engineering Association by the third rail clearance diagram, which was adopted by the Association at its March meeting, 1912, I have investigated this matter and would suggest that the attached diagram be referred to the Standing Committee on Iron and Steel Structures with the recommendation that as the established bridge clearance line indicated on the diagram between points "A" and "C" practically coincides with point "B" on the third rail clearance diagram, that this line be modified so as to pass through point "B," and that portion of the line between "A" and "B" which is shown dotted on the diagram be eliminated and in place thereof the clearance line for permanent way structures be substituted on roads where electric equipment is likely to be used."

This subject was referred to the Committee by the Secretary on October 24, 1912, and is still under consideration. There seems to be a general agreement that a change in the diagram should be made but there is much to be said in favor of a more radical change than that proposed by Mr. Kittredge. The matter is to receive further study by a sub-committee which will investigate the dimensions of equipment passing over the railroads and propose a new diagram.

A letter from the Secretary dated September 18, 1912, informs the Committee that "the Railway Signal Association has intimated that it might be desirable to have a conference with the proper committee of this Association on the question of joint action in the direction of adapting designs of drawbridges to the signal and interlocking appliances required." He then requests, at the suggestion of President Churchill, "will you kindly get in touch with Mr. C. C. Rosenberg, Secretary of the Railway Signal Association, and arrange a conference?" At the joint meeting above mentioned an extended discussion was held and provisions made for a joint committee consisting of two members from Committee XV of the American Railway Engineering Association, two members from the Railway Signal Association and two members from Committee X of the American Railway Engineering Association, provided that Committee X shall elect to co-operate in the work. The following gentlemen were chosen as members of the joint committee: Mr. R. C. Johnson, chairman; Mr. G. W. Chappell, of the Railway Signal Association, and Mr. C. E. Smith and Mr. O. E. Selby of the American Railway Engineering Association.

The President:—The Chair suggests that the rules given on pp. 86-91 be read by the Secretary, and if there is no objection to any paragraph, the Secretary will proceed with the reading just as we did this morning.

(The Secretary read the first nine paragraphs on page 86.)

Mr. W. R. Edwards (Baltimore & Ohio):—It seems to me questionable whether we should insert an instruction of this kind which is entirely contrary to the mill practice at the present day, and which it is impossible for the inspector to carry out. The surface inspection of the material in the mills cannot be carried on under the method by which material is rolled and shipped at the present time. I ask if the Committee has considered that point in drawing up these instructions?

Mr. Himes:—That matter has been fully considered by the Committee and a number of the Committee members are quite well versed in the practice that prevails at the mills and at the shops. It is well understood that the mill inspection in no instance is perfect, or approximates perfection, to any particular degree, and yet it is the thought of the Committee that it is best to outline a practice which is worth striving for and which has been followed in the past to a very considerable extent, and without which it is very probable that the present uniform quality of the output of the mills would not exist.

The particular question raised by Mr. Edwards is cared for in Section 10, which says, "Report promptly the shipment of any material from the mill, whose surface inspection has been waived. Such material should be examined by the shop inspector."

It is true that a large percentage of the material shipped from the mills has not been carefully inspected by the inspectors of the railroad companies or the bureaus, but there are many instances in which such material is inspected at the mills rather more than one might suspect from the current comment of inability to secure such inspection. It is also well understood in current practice by the bridge companies, and by the mill men, too, that because of the loss of time that might result in handling the material at the mills it is better to have much of it shipped directly to the shops and if there found defective to have it replaced, and while the bridge companies protest against carrying the burden, nevertheless they do carry the burden, that is, in some way they arrange with the mills so that our inspectors do have the opportunity of rejecting the material in the shops if found defective, and that is the place where the most efficient surface inspection can be had.

Mr. A. F. Robinson (Santa Fe):—It seems to me that while we are covering that inspection we should say something to the effect that the inspectors must be free to examine the material whenever the mill men are ready to ship. As a matter of fact, they cannot do the surface inspecting and examine the plates or angles on more than one side. It is next to impossible to have material turned for careful surface inspection under present conditions. It does not seem to me that we have it covered in the present specifications.

Mr. A. W. Carpenter (New York Central & Hudson River):—Our Chief Mill Inspector, Mr. F. H. Brinton, confirms what has been said about the impossibility of complete surface inspection at the mill. I will read an extract from a letter from him which may be of interest:

"Owing to the inability of mill inspectors to examine the finished mill product at the mill and before shipment, but little mill inspection is now made along the lines as at first set out. In order to fully comply with this provision it would be necessary to have a number of inspectors at the mill day and night, and who, under the present mill arrangement, would have to be stationed at the hot beds beyond the finishing rolls. The mills have not usually provided the room or facilities for laying out and turning over of the structural material, which would be needed if they were required to handle the product for surface inspection, for instance at the loading wharfs, or sheds (rails they have provided for). They would object strenuously to such an arrangement, and it would certainly make endless contention and confusion. In lieu of this, they have their own inspectors who look over the surfaces and are instructed to throw out all defective material. The foreign inspector accepts the material on test, they ship it forward, and if it is found to be defective on arrival at the shops where it is to be fabricated into the members intended, by the shop inspector, it is thrown out and ordered to be replaced."

Mr. C. H. Cartlidge (Chicago, Burlington & Quincy):—I think the explanation by the Chairman, of paragraph No. 10, covers existing mill practice as well as it is possible for us to do so with a specification or set of rules and obtain the surface inspection which we require. We should, I think, get surface inspection at the mill to the greatest practical extent.

(The Secretary read rule 10.)

Mr. Thos. Earle (Pennsylvania Steel Company):—I wish to say that some of the shops object seriously to having mill inspection performed at the shop as implied by the last part of Section 10. It causes the shop unnecessary expense which they do not care to bear if they can avoid it. I have no objection to Section 9.

(The Secretary read rules 11 to 16, and rules 1 to 16 of the Instructions for the Inspection of the Fabrication of Steel Bridges.)

Mr. A. W. Carpenter:—What does "camber is not reversed" mean?

Mr. Himes:—I will have to ask some other member of the Committee to explain that. I do not plead total ignorance, but think it would be a little unsafe for me to explain the matter in detail.

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis):—There is a certain liability of riveting the sole plates or base plates on the wrong side of the girder. As some are designed, the top flange is just like the bottom flange, and they might be mixed up by careless shop work, and the base plate riveted on the top flange, instead of the bottom flange. I think that is what the clause means in referring to the camber.

Referring to the checking of the base plates, the most important thing to check is to see that the girder flange is properly prepared to receive the sole plate; in other words, that the web or fillers do not project in such a way that the sole plate, when drawn up by the rivets, will be curved and not plane, and that the flange angles, to which the sole plate is riveted, are not bent out of position. The angles are rolled, not to a right angle, but as a general thing to something less than a

right angle, and if the thin sole plate is riveted to the angles in that condition it will be curved and not planed. It is true that usually the specifications require the bottom of the girder to be faced, machined, before the application of sole plate, but that does not occur in all specifications, and this is intended, as I understand it, to cover cases of that kind.

Mr. Earle:—I would suggest in place of "camber" that the word "bevel" be used, and then I think the clause will have a definite meaning.

The President:—The Committee accepts that.

(The Secretary read rules 17 to 20 on page 88.)

Mr. A. W. Carpenter:—On that last clause there is another point that is very important and that is the pinholes should be bored truly square to the member. I think that is as important as the other points mentioned and it would be well to include it.

Mr. Himes:—The Committee would be willing to make that paragraph read: "Examine and measure bored pinholes carefully to insure proper position, dimension and spacing and smoothness of finish."

Mr. A. W. Carpenter:—I do not think that makes the point very clear. These are directions for inspectors, and they should know just exactly what that means. It should be a little more comprehensive.

Mr. C. E. Lindsay (New York Central & Hudson River):—Will the Committee accept the wording, "direction of the hole?"

Mr. Himes:—The word "position" is more comprehensive than the word "direction," and if I had an inspector who did not know what that meant, I would get a new inspector.

(The Secretary read rules 21 to 23 on page 88.)

Mr. Earle:—It seems to me it is hardly proper in instructions of this kind to tell an inspector to do something that is not in the contract. It says, even if the contract does not call for the assembling, that the inspector shall require it. That seems hardly proper.

Mr. Himes:—In regard to this criticism, I may not quote our specifications correctly, but it is customary to require first-class workmanship, and it has been our experience with work in bridge shops that there is not much question about what first-class workmanship is, and if you request any of the bridge manufacturers to do something which clearly, and in accordance with current custom, makes the good practice, they are not likely to object to it. Of course, it is true the contractors every once in a while say to you some requirement is not in the contract or specifications. These matters have to be handled in a rather broad way, and it is not a very difficult matter to determine whether a contractor is anxious to turn out a first-class job or to turn out the cheapest job he can, and the action of the inspectors should be governed by the attitude of the contractor. I do not believe that an inspector or Engineer need have any dispute or controversy with a bridge company over a matter of that sort.

Mr. Paul L. Wolfel (McClintick-Marshall Company):—The clause is decidedly objectionable, because it will invite the inspector to ask for an assembling and save himself the trouble of carefully measuring up the connections, which ought to be a part of his duty.

Mr. Cartlidge:—I move that the Committee be asked to consider paragraph 23 further. I believe with Mr. Earle and Mr. Wolfel that this clause will cause difficulty. It is true, as Mr. Himes says, that many shops arrange for such assembling as is required by the Engineer or inspector, without objection, but there are all kinds of bridge shops, as well as all kinds of inspectors, and unless the question of assembling is set forth in the specifications, it should not be set forth in these instructions. It is easy to cover the matter in such way that there is no question as to what is required, and that should be done.

Mr. H. A. Lloyd (Erie):—Is there not a clause in almost every contract which states that every facility will be given for inspection and the necessary labor furnished, which covers a great deal of this ground?

Mr. Selby:—It seems to me there is very little involved in the objections made. In the first part of the sentence it is provided that the inspectors should have the assembling of trusses and girder spans required by the specifications carefully done. I do not think the speakers have objected to that. That is part of the contract. The second part reads that if a large number of duplicate parts are to be made, the inspectors shall insure the accuracy of field connections by having an occasional part assembled with its connecting member. The latter is the only part to which an exception has been taken, as I understand it. There are very few cases that would not come under that. Ordinarily the specifications will require shop assembling. Certainly the tendency is in that direction in the best shops, regardless of whether it is required by the specifications or not. Under this clause the inspector could not require the assembling of any parts if there was only one part or only a few parts to be duplicated, but could require it only in the case of a large number of duplicate parts.

Mr. Himes:—There are several clauses in the Manual which bear on this subject, which I would like to read. Paragraph 114 on page 418, under the heading "Workmanship," reads as follows:

"All parts forming a structure shall be built in accordance with approved drawings. The workmanship and finish shall be equal to the best practice in modern bridge works. Material arriving from the mills shall be protected from the weather and shall have clean surfaces before being worked in the shops."

Paragraph 124 reads as follows: "Riveted members shall have all parts well pinned up and firmly drawn together with bolts before riveting is commenced. Contact surfaces to be painted."

Paragraph 121 reads as follows: "When general reaming is required it shall be done after the pieces forming one built member are assembled, and so firmly bolted together that the surfaces shall be in close contact. If necessary to take the pieces apart for shipping and handling, the respective pieces reamed together shall be so marked that they may be reassembled in the same position in the final setting up. No interchange of reamed parts will be permitted."

That does not cover the subject quite so completely as the gentlemen who have criticised the instruction have in mind. The objection appears to be that if this instruction should be adopted the inspector might at some time impose a hardship on the bridge companies by asking them to do a large amount of work which is considered by the bridge companies to be unnecessary. I believe there have been occasions when bridge companies have been imposed upon by inspectors, but my experience would lead me to believe that this danger is exceedingly remote.

Mr. Cartlidge:—Mr. Chairman, I beg to be absolved from the accusation. The conflict of these rules with the specifications, as the case stands now, will inevitably bring about dispute between the client and the bridge company. If the specifications as printed in the Manual do not specify the required amount of fitting, in the way of assembling in place before reaming (and none of the paragraphs read by the Chairman refers to that, but to the assembling of the individual pieces forming one member)—if the specifications as printed in the Manual do not show that, then they should be amended to cover the work of assembling that is desired, and should not be put in the shape of instructions to inspectors.

Mr. A. F. Robinson:—It seems to me that this paragraph, instead of being remodeled, ought to be taken out altogether. It is useless to give instructions to inspectors that ought to be put in the specifications or put on our plans. I think we ought to omit the paragraph entirely.

The President—Is that on account of the number?

Mr. A. F. Robinson:—Twenty-three? Yes, sir. (Laughter.)

The President:—Those in favor of referring this back to the Committee will signify by saying aye. It is referred back to the Committee.

Mr. A. W. Carpenter:—It seems to me there is a little redundancy there—"the accuracy of the driving fits"—it seems to me that "driving fit" is pretty nearly a definition of accuracy in itself.

Mr. Himes:—I think Mr. Carpenter is correct about that. A driving fit is pretty definite. It seems to be an open question whether it is worth while to say anything more about it. Perhaps some member of the Committee has views on it which he would like to state.

Mr. A. W. Carpenter:—I would suggest to omit the word "driving"—that might help.

The President:—The Committee will accept that.

(The Secretary read paragraphs 24 to 34.)

Mr. Lindsay:—I move that paragraph 34 be referred to the Entertainment Committee. (Laughter.)

(The Secretary read paragraphs 35 to 41, on page 89, and paragraphs 1 to 23, on pages 90 and 91.)

Mr. A. W. Carpenter:—There are a few additional clauses which seem to me might be added to this list of instructions that are quite as important as most of those mentioned. One of them is to check the

dimensions of the material used in each member. I see no reference to that.

Mr. Himes:—The requirement which Mr. Carpenter mentions is in the specifications. It is stated under "Mill Inspection" that all material should be properly calipered or checked by weight.

Mr. A. W. Carpenter:—It does not seem to me that that entirely covers the case, because after the material gets in the shop, some of it might be put in the wrong place.

Mr. Himes:—In regard to putting the material in the wrong place, it might be interesting to recite an experience of the Chairman. On two different occasions when starting out to erect bridges, I had been fortunate in securing the services of very excellent young men whose experience had not been very large in that particular kind of work, and I had cautioned them each in turn, very carefully and very fully, to observe the match marks on the plans, and see that no built-up member should be placed in the wrong position in the structure. In spite of these careful, full and complete instructions in advance of the work, in each instance some built-up member was placed in the structure in the wrong position. Now, I think we cannot hope to eliminate such things absolutely. That is an argument in favor of what I am disposed to object to. I hardly see how it would be of any use to go into a shop and say to an inspector: "You must not have any material put in the wrong place." I think the experience and knowledge of the inspector would necessarily be such that a specific statement of that sort would hardly be expected or worth while.

Mr. A. W. Carpenter:—I think this is a very excellent set of rules and covers pretty nearly everything, but it seems to me that the fundamental thing is to see that the proper material goes into the members, and if there is anything that we want to call the attention of the shop inspector to, it is the checking of the material in the members to see that everything corresponds. I make a motion that a clause be added requiring the inspector to check the material in each member.

Mr. Selby:—Clause 8 seems to cover the question raised by Mr. Carpenter. Care in assembling is a somewhat general expression, but proper attention to the assembling would include checking the dimensions of the material assembled.

Mr. E. A. Frink (Seaboard Air Line):—In rising to second Mr. Carpenter's motion, I would like to say I think the question of the size of the material is of importance. It is not at all unusual to have members of the same size of varying weights on the same structure.

The President:—The Committee have no objection to that clause; if it be the sense of the convention that that be added, they will agree to it. The Chair will, therefore, put the question.

(Motion carried.)

Mr. A. W. Carpenter:—I have another point. There is nothing said about the inspector checking the weighings, or checking the accuracy of the scales. These, I submit, are also fundamental things.

The President:—If you will draft that clause and give it to the Committee they will accept it. Have you it written out?

Mr. A. W. Carpenter:—No, sir; but I have another point. We have found in our inspection a number of things that gave us special trouble. One is in regard to stiffeners. Inspectors seem to go wrong on that point frequently—that is, as to where the stiffeners should bear—and in our own instructions to inspectors we cover that point specifically. It seems to me that perhaps other inspectors would have the same trouble. It might be well to have a clause on that point.

The President:—What do you suggest?

Mr. A. W. Carpenter:—I would suggest that the inspector should see that stiffeners bear at all points of concentrated loading, at the masonry bearings and against the top flanges of deck girders. That is not perhaps properly worded, but that is the idea.

Mr. A. F. Robinson:—It seems to me the points raised by Mr. Carpenter are, or ought to be, covered by our regular specifications and by the plans, and they have no business to leave the instructions to the inspector. He has general instructions to see that the work is built in accordance with the plans and specifications, and he ought to have sense enough to follow it out.

The President:—If there are no further comments, we will proceed with the other section.

Mr. W. R. Edwards:—I think that this paragraph is incomplete in that it does not lay sufficient emphasis on heating the rivets uniformly throughout. It warns against overheating, but does not say anything about the rivets being sufficiently heated throughout their whole length. I find that there is great difficulty in having the rivets heated sufficiently and uniformly.

The President:—Have you any suggestion to make, Mr. Edwards?

Mr. Edwards:—I would suggest that the Committee include that point in the instructions, to insure that the rivets are sufficiently heated and not overheated.

Mr. Cartlidge:—May I suggest "to watch the heating of rivets to prevent underheating, or overheating, and make sure that the scale is removed?"

Mr. A. W. Carpenter:—It is not always desired to re-erect old structures. I would suggest after the word "removed" we insert "which it is desired to re-erect."

The President:—The Committee will accept that.

Mr. A. W. Carpenter:—I have a number of additional clauses to suggest. It happens very frequently that a number of parts are bent in erection, especially lattice bars on compression members, and I think a clause requiring the straightening of such parts, especially mentioning lattice bars, would be desirable.

Mr. Himes:—If the bending that is referred to is trivial, what is done with it doesn't matter very much. It may be straightened. If it

is not trivial, I would, in general, object to the straightening. I would want it cut apart and new pieces added.

Mr. Lindsay:—I was going to comment on the absence of any instruction requiring the inspector to look out for damage to new members, either in the unloading or the erection. I do not see that there is anything of that kind here. I think another point to be guarded against in the unloading and storing of material is to prevent the accumulation of water on members.

The President:—Have you any motion to make, or will we ask the Committee to take these matters under consideration for any changes in the future?

Mr. Lindsay:—I would like to add an instruction to avoid the storing of material in such a manner that water will accumulate on the members. Rule 14 seems to cover the other point.

Mr. Himes:—I would say, in regard to these additions and changes, that the Committee understands very well that many things have not been said that might be said, and we feel quite certain that we could add very largely to the number of instructions that have been printed and still leave some things unsaid. It has been the thought of the Committee that perhaps we had said enough to justify its publication in the Manual. We are not averse to adding some of these clauses which have been mentioned. This one by Mr. Lindsay has much merit. The matter which it would seem to me important for the Association to decide is whether they shall publish any portion of this in the Manual, or whether we shall hold it up for another year and enlarge upon it.

Mr. A. F. Robinson:—It is a large proposition, to get up an acceptable set of specifications to cover the points under discussion. These specifications show that the Committee has done admirable work thus far. I think there are many points which have not been properly covered, or could be improved upon. I, therefore, move you, sir, that these specifications be accepted as tentative, or that the work be referred back to the Committee for a report another year. In view of the importance of these specifications, we ought to have them put in the very best shape possible. I think the specifications as now submitted can be materially reduced as to size or as to space occupied and still express all that is necessary. I, therefore, move that the specifications—all three of them—be referred back to the Committee.

Mr. J. L. Campbell (El Paso Southwestern):—Before that motion is acted upon I want to move as a suggestion to the Committee, or a disposition of the matter now, a reconsideration of the second paragraph of rule 28 under "instructions for the inspection of the fabrication of steel bridges," so as to read as follows: "Make sure that the specified accuracy of driving fits for bolts or keys and similar parts is attained." My reason for that is that this apparently, as now worded, is an authority to the inspector to determine the accuracy of the fit. I think the accuracy of the fit ought to be determined by the specifications.

Mr. George W. Kittredge (New York Central & Hudson River):—In reference to Mr. Robinson's motion, it seems to me that we had better have these instructions rather than have none, and it is entirely within the province of this Association, next year, or the year after, if they see fit, to change them. I, therefore, shall vote No on Mr. Robinson's motion.

(Motion lost.)

The President:—It is now in order to adopt these instructions as amended, for insertion in the Manual. Before putting the motion, however, the Committee desires to accept Mr. Robinson's suggestion, if you will allow a reconsideration in part in reference to paragraph 23, page 88, that it be omitted. Now, by action of the convention it was referred back to the Committee. They will consider it as omitted, and it will be taken up as one of the matters for future improvement. They have accepted that. If there is no objection, we will consider rule 23 as referred back to the Committee in the sense of rewriting it as an additional clause next year, but it will be entirely disregarded in this action of accepting the three sets of instructions for printing in the Manual. Those in favor of adopting these instructions for publication in the Manual, please signify by saying aye.

(Motion carried.)

The President:—The Committee is relieved, with the thanks of the Association.

DISCUSSION ON TRACK.

(For Report, see pp. 97-131.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON TRACK.

W. McC. Bond.	C. E. Lindsay.	Earl Stimson.
A. W. Carpenter.	Hunter McDonald.	John G. Sullivan.
L. C. Fritch.	C. A. Morse.	Edwin F. Wendt.
J. B. Jenkins.	G. J. Ray.	

The President:—The report of the Committee on Track will be presented by the Chairman, Mr. J. B. Jenkins, and the Chairman will outline the method to be pursued in considering the report.

Mr. J. B. Jenkins (Baltimore & Ohio):—The Committee wishes to consider conclusion 2 first. It is found on page 130, Bulletin 152. The typical plans are found on the inset, immediately after page 131. I would move the adoption of this conclusion.

Mr. C. E. Lindsay (New York Central & Hudson River):—The "bill of material" is really a "bill of timber." The Committee should use the term "timber" instead of the word "material."

The President:—The Committee will accept that.

(Motion carried.)

Mr. Jenkins:—Your Committee recommends for adoption and publication in the Manual, as desirable agencies to obtain a better class of section foremen (reads clauses a, b and c, page 130). I move the adoption and publication in the Manual of conclusion 3.

(Motion carried.)

Mr. Jenkins:—Your Committee recommends for adoption and publication in the Manual the "Table of Functions of the Ten-Chord Spiral" submitted herewith, as supplementing and completing the table on pages 102-110 of the Manual, and superseding the table on page 111. I move the adoption of conclusion 4.

(Motion carried.)

Mr. L. C. Fritch (Chicago Great Western):—I move the reconsideration of conclusion 3. On page 131 the Committee asks that conclusions 2 and 3 be reassigned them. That conclusion is hardly in shape to be published in the Manual.

Mr. Jenkins:—The Committee do not recommend that conclusion 3 be reassigned, but subject 3. The subject is a very broad one, and will keep the Committee busy for the next twenty years, I presume; consequently, we desire to continue the study. Conclusion 3, while it happens to be on the subject designated by the same number, is only one conclusion that we have reached in our early investigation on this subject. It is only an extremely small part of the subject that we have undertaken to study.

Mr. L. C. Fritch:—That was my reason for asking that it be reassigned. It hardly seemed to me to be fit matter to be put in the Manual.

Mr. Jenkins:—The Committee has reached a conclusion in regard to desirable agencies to obtain a better class of section foremen. Subject 3 is "Economics in Track Labor." Conclusion 3 is a very small portion of the whole subject of economics in track labor. The Committee has reached the three conclusions (a), (b) and (c), given as conclusion 3, as a minor part of the subject of economics in track labor. We have barely scratched the subject.

The President:—The motion is to reconsider the action of the convention in adopting conclusion 3.

(Motion lost.)

Mr. Jenkins:—Conclusion 5 does not in any way change the table itself or the meaning of the table, but simply makes clear what these dimensions refer to. If anyone takes the trouble to compute the table, he will find these distances refer to the theoretical point, and it should be clearly so stated in the heading. I move the adoption and publication in the Manual of this conclusion.

The President:—This is simply a correction of the Manual.

(Motion carried.)

Mr. Jenkins:—I would move the adoption and publication in the Manual of section (a) of conclusion 1, Tie-plates—general principles to be followed in the design. These general principles are to be found on page 98, Bulletin 152.

Mr. L. C. Fritch:—I would suggest that the headings of specifications be read.

Mr. C. A. Morse (Santa Fe):—Under the heading, "Tie-plates," I notice one clause, "They shall not be less than 5/8 of an inch thick along either edge of the base of the rail."

The President:—We will carry out the suggestion and read the heading of each section, and take this up when we reach it.

Mr. C. A. Morse:—It does not seem to me that we should include here the specification that tie-plates should not be less than 5/8 of an inch thick, for the reason that it is good practice on a great many roads to use tie-plates a half an inch thick. We have over forty million of them on the Santa Fe, and we have found no trouble with the half-inch thickness. The next clause covers all that is necessary, and this clause should be omitted.

Mr. Earl Stimson (Baltimore & Ohio):—I move the third paragraph specifying 5/8-in. thickness be stricken out and that it be considered that the thickness of the plate is covered by the next paragraph, for the reason mentioned by the preceding speaker, that there are comparatively few tie-plates now in use 5/8 of an inch thick. By specifying this unusual thickness, it condemns as bad practice the present thickness used on the majority of the roads.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—That conclusion was reached after a very thorough canvass by the Committee of what is being done, and the kind of tie-plates being used by the various roads. While it is a fact that a big majority of the tie-plates now

in use are less than 5/8 in. in thickness, we found very few people who were not perfectly willing to state that it is a mistake to use less than 5/8-in. plates under the edge of the base of the rail. You will notice the wording gives you permission to cut your tie-plate down by beveling at the end, or by reducing the thickness under the rail, but on the edge of the rail we insist it is right and good practice not to have the plate less than 5/8-in. thick, and I think it is a mistake for the Association to go on record favoring anything thinner than 5/8-in. The next paragraph merely relates to thicker plates, which must necessarily be used in certain places, where your plates are longer than they ordinarily would be, on account of the peculiar fastening which you might use or the width of the rail base.

Mr. C. A. Morse:—The gentleman says he made an investigation of the roads of the country and found the practice called for 5/8-in. I would say I think the Santa Fe has more tie-plates than any other road in the country, as we have between forty and forty-five million at the present time. We have never had any of the half-inch in thickness that showed any sign of weakness. I think the Harriman Lines follow the same practice. Most of the western roads are using a softwood tie, which would develop the weakness in the half-inch tie-plate if it existed.

Mr. John G. Sullivan (Canadian Pacific):—The function of tie-plates has changed in the last few years. I agree with the Committee that the function of the tie-plate at present is to distribute the load, and when they say that the length of the plates shall not be less than the safe bearing area divided by the width, why they have said all that is needed. If the road finds that half-inch tie-plates buckle and they figure out the bearing area, they should thicken them. We are using plates half an inch at one side and three-eighths at the other, and we are not having any trouble with buckling. I shall vote against the minimum of 5/8-in. as being a waste of money, at least on some roads.

The President:—Those in favor of eliminating paragraph 3 entirely signify by saying aye.

(The paragraph was eliminated.)

Mr. L. C. Fritch:—I would ask if the Committee will insert "per square inch" on the first line of the table under "Physical Properties and Tests?"

The President:—The Committee will insert that, so that it will read, "55,000 lbs. per sq. in."

Mr. J. B. Jenkins:—I wish to announce that the Committee by letter-ballot amended the specification in regard to spike holes so as to read, "The spike holes must be clean cut, without burrs, and the plates must not be cracked or bent out of shape in punching the holes."

The Committee recognizes in the majority of cases it is best to punch the holes from the top, and that should be the general practice, but there are special cases where the holes should be punched from the bottom, where the punching cannot be successfully done from the top.

Mr. Lindsay:—In connection with the section relating to the stamp-

ing of plates, I think that would be improved if it read, "All plates must be stamped on the top side, outside of the rail seat, with the prescribed mark."

I make that suggestion because on many roads we have our standard tie-plates plan which gives a distinctive letter or number for the tie-plates that is to be used with certain weights of rails. There are certain letters which are to be used for the tie-plate at the joint, and others at the end of the angle bar. I believe, if it is written to read in the form I have suggested, it would be more universally applicable.

The President:—The Committee will accept that amended reading.

Mr. Lindsay:—I do not know of any metal which deteriorates so rapidly with rust and corrosion as that in tie-plates. The Committee in one of the other specifications recognizes the advantage of oiling the article to prevent rust. I believe it would be a good thing to have tie-plates oiled, and I suggest that the following be added as a separate requirement, under "Workmanship and Finish," "Tie-plates must be oiled to retard corrosion."

Mr. Jenkins:—The Committee will accept that addition.

Mr. Lindsay:—Under the heading, "Shipping," at the end of the specifications for steel tie-plates, I would like to substitute the following: "Tie-plates shall be wired together in bundles of uniform number, weighing not to exceed 100 lbs. and properly tagged."

Mr. Jenkins:—The Committee will accept that suggestion.

The President:—A motion was made and seconded that the general principles to be followed in the design of tie-plates, as amended, be adopted for publication in the Manual.

(Motion carried.)

Mr. Jenkins:—I move the adoption for publication in the Manual of the Specifications for Steel Tie-Plates, as amended.

(Motion carried.)

Mr. Earl Stimson:—I inquire whether the suggestion regarding the oiling of tie-plates was accepted by the Committee? I wish to protest against the clause being put in the specifications. The oiling of the tie-plates will add to the cost. The oiling will not be sufficient unless you keep on oiling the tie-plates after they are in the track.

I, therefore, make a motion that the clause regarding the oiling of the tie-plates be omitted from the specifications.

The President:—Will the convention reconsider the action taken and omit the clause relating to the oiling of the tie-plates?

(The matter was put to vote, and it was decided to reconsider.)

The President:—Now, those in favor of adopting the specifications, as amended, without any reference to oiling the tie-plates will signify by saying aye; contrary minded no.

(Motion to adopt the specifications, as amended, without reference to oiling tie-plates, was carried.)

Mr. L. C. Fritch:—I move that the specifications for wrought-iron tie-plates be amended to harmonize with the amendments in connection

with the specifications for steel tie-plates, which are substantially the same as the specifications for wrought-iron tie-plates.

The President:—That will save considerable time and is a proper motion to make.

Mr. John G. Sullivan:—There might be a question of the oiling of wrought-iron tie-plate, but no question of the oiling of the steel tie-plate.

Mr. Lindsay:—There seems to be some doubt as to whether the paragraph with regard to oiling was cut out.

The President:—It was cut out.

Mr. L. C. Fritch:—I think you will find that the rusting of steel tie-plates is a serious matter. The cost of oiling before shipment is a very small matter, and I think it is very important. I think the oiling of steel tie-plates should be included, but I suppose it is too late now.

The President:—The motion was put to eliminate reference to oiling the tie-plates, and the motion was carried.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—If some gentleman, who advocates the oiling of tie-plates, would enlighten us on the cost of it, and the advisability of it, I would move to reconsider the question.

Mr. Lindsay:—I am sorry I cannot enlighten you on the subject, but believe it is very vital for the steel tie-plate. The steel tie-plates apparently go to pieces very rapidly before they get into the track, more so than they do after they get into the track, where the action on the rail seat, for instance, keeps it bright. I have seen tie-plates that seemed to corrode into their constituent sheets before they were put into the track, and you see no such condition after they are put into the track, except when it is caused by brine. I believe the dipping of the plate in oil after manufacture and before shipment will be a decided improvement, at very slight cost.

The President:—Would it not be well for this Committee to study the subject?

Mr. Earl Stimson:—I have had experience with tie-plates which have been oiled and those which were not oiled, and I will state that the oiling practically has no effect on the life of the tie-plate against rusting.

Mr. A. W. Carpenter (New York Central & Hudson River):—We made some tests and found that steel plates coated with linseed oil began to rust within two or three months, when exposed to ordinary weather conditions. I do not think that oil can be considered as much of a protection. The only effective protection to the tie-plates would be to paint them.

Mr. Ray:—At the present time we are preparing to oil all of our fastenings in the track, and if we have to do it once in every three months, I believe it is going to pay. We have a special rig, and can oil 20 miles of track a day, easily. The oil is spread on both sides of the rail, down below the top of the head, and to the end of the tie-plate. The oil is spread with a sprayer. We have been doing this for some six

months, and we find it is retarding the rusting of the plates. When you come to use screw-spikes, as we are doing, at a pretty high cost, heavy plates at a big cost, along with the automatic signals, and the trouble we have from rusting on account of brine drippings, and all those things considered, we think we will get full value for the extra expense in oiling the tie-plates and track fastenings generally. I would be very glad to see the tie-plates oiled at the factory.

The President:—The motion before the house is that made by Mr. Fritch, that the specifications for wrought-iron tie-plates be amended to harmonize with the amendments in connection with the specifications for steel tie-plates.

(Motion carried.)

The President:—Is it the desire of the Association that the subject of Specifications for Malleable Tie-Plates be read paragraph by paragraph?

Mr. Lindsay:—I suggest that the Specification for Malleable Tie-Plates be read by caption.

Mr. L. C. Fritch:—Under "Workmanship and Finish," it is stated that the length and width shall not vary more than 1/16 in. from the dimension shown, while in the wrought-iron and steel specifications it is given as 1/8. What is the reason for the difference?

Mr. Jenkins:—The malleable tie-plates can be made to conform better to the dimensions than the steel tie-plates can.

Mr. Lindsay:—I move that the "Shipping" article be changed to agree with the same article under steel tie-plates and wrought-iron tie-plates.

The President:—The Committee will agree to that.

Mr. Jenkins:—I move that the specifications for malleable tie-plates be adopted.

(Motion carried.)

Mr. Jenkins:—I move that the matter on pp. 101 and 102, in regard to facts and general principles to be taken into consideration in the design of track bolts, be adopted.

(Motion carried.)

Mr. Lindsay:—We have had some difficulty at times with manufacturers shipping the bolts without the nuts, unless we specified a threaded nut with each bolt. I think it should be made clear in our specifications that a threaded nut should accompany each bolt, and it would avoid some confusion if it was definitely stated.

Mr. Jenkins:—That is provided for under "Marking and Shipping," that "When the bolts are shipped they shall have the nuts applied for at least two threads."

Mr. John G. Sullivan:—There is very little said in the report about the fit of the nuts. We have a great deal of trouble in that respect. We use the Harvey grip threads, and it is necessary to specify the tension which must be used in putting on the nuts. Our principal trouble is with the nuts—they get them too loose or too tight, and I would like to see that point covered.

Mr. Lindsay:—Under "Workmanship and Finish," I would like a clause somewhat as follows inserted: "Care must be taken to avoid damage to the metal by overheating in manufacture."

Mr. Jenkins:—The Committee will accept that.

Mr. Ray:—In answer to Mr. Sullivan I will say at the top of page 103 the statement is made that the heads and nuts shall be free from checks or burrs of any kind, and that they shall have the U. S. standard upset thread, unless otherwise specified.

Mr. John G. Sullivan:—We are having less trouble with nuts with the Harvey grip thread than we had with the "V"-shaped thread which we used to get. In some cases the nuts came from one factory and the bolts from another and it often happened that the nuts were so tight that they could not be put on with any reasonable expense, and in other cases they were so loose that it was impossible to keep them tight. I think there should be something in the specifications to cover this point.

Mr. Ray:—I think the trouble is due principally to the way the matter is handled at the mill. You can cut threads on bolts all day long with a machine at the mill, and you will find that the nuts will not fit all of the bolts at night. When they come to fit the nuts to the bolts they must fit each one separately, and if they will do this, there will not be any trouble. In a good mill they have men who fit the nuts to the bolts, and some times they will have to try two or three nuts before they get one which will properly fit the bolt. If care is taken in fitting the nuts at the mill there will not be any trouble on this account.

Mr. Jenkins:—I move that the Specifications for Track Bolts be adopted, as amended, for publication in the Manual.

(Motion carried.)

The President:—In connection with the specifications for ordinary track spikes, it is understood that any changes made in the previous specifications, that should be made in these specifications to make them harmonize with the others, will be made in these also.

Mr. L. C. Fritch:—I think somewhere in the specifications we should show how the length of the spikes should be measured, whether it should be the length over all, or if the measurements should be under the head. There is a great difference of opinion on that point, and I think we should definitely fix the measurement; preferably the length should be measured under the head.

Mr. Lindsay:—On our line we overcome that by getting out a standard drawing of a spike.

Mr. Jenkins:—The Committee is ready to accept the suggestion offered by Mr. Fritch. The present rule says, "The length shall not be less nor over ¼ in. more than the dimensions shown."

Mr. L. C. Fritch:—Even under that rule, if you do not send a plan of the spike, the manufacturer is at sea. I had a manufacturer recently tell me that this is a point they would like to have settled for their own benefit.

Mr. Jenkins:—The Committee will amend the paragraph referred to by having it begin, "The length under the head," etc.

The President:—That will undoubtedly be acceptable.

Mr. Jenkins:—I move the adoption, for publication in the Manual, of the Specifications for Ordinary Track Spikes.

(Motion carried.)

Mr. Lindsay:—I ask the Committee if they have considered the method of making the thread on the screw-spike, or if they think it necessary to specify how the thread should be formed?

Mr. Ray:—There is only one way that the thread can be made economically, and that is rolled. When you buy them, you will find that the manufacturer who makes them in any other way will not be able to compete with the markets. I do not think there is any question but what the method of manufacture will take care of itself. You have to roll them to make them economically.

Mr. John G. Sullivan:—Many spikes are shipped in boxes. I think the paragraph should read, "Good serviceable boxes, kegs or bags."

Mr. Jenkins:—Mr. Safford suggests that we can change "kegs or bags" to "packages," which will cover all sorts of containers. The Committee will change that by making it read, "shall be packed in good serviceable packages."

Mr. L. C. Fritch:—I ask about the necessity for oiling the spikes in the case of screw-spikes, when we did not think it necessary to have the tie-plates oiled.

Mr. Ray:—For the same reason that you oil the bolts, to keep them from rusting. It does not cost any more to have the oiling done than to have them shipped without oiling.

Mr. Lindsay:—I am not sure whether screw-spikes are made by hydraulic press or not. The ordinary track bolt is oiled in the process of cutting the thread, and it is possible that may be the case in the rolling of the screw-spikes, but if they are made by an hydraulic method or stamped out, that might not occur, and the oiling of the spike for the prevention of corrosion might be a proper specification.

Mr. Ray:—A rolled thread bolt cannot be oiled as it is rolled, it must be oiled afterward. The same thing is true of the screw-spikes.

Mr. Hunter McDonald:—I ask the Committee why they cut out the use of Bessemer steel in connection with screw-spikes as well as bolts, and have permitted the use of Bessemer steel in tie-plates?

Mr. Jenkins:—We think a better quality of material is required in screw-spikes and bolts than in tie-plates.

Mr. Hunter McDonald:—One of the disadvantages of eliminating the Bessemer steel is that you confine yourself to a smaller number of bidders; we have recently had a lower price submitted for Bessemer steel than for Open-Hearth. In the case of cut threads, the manufacturers claim they can get a much more accurate thread on the Bessemer than on the Open-Hearth. I am talking of bolts now. I do not know how true that is.

The President:—The Committee has stated that they prefer the rolled thread to the cut thread.

Mr. Hunter McDonald:—I agree with the Committee on that, but at the same time we cannot always have our way, and sometimes we have to specify cut threads.

Mr. Jenkins:—I move the adoption and publication in the Manual of the Specifications for Screw-Spikes.

(Motion carried.)

Mr. Lindsay:—The Specifications for Anti-Creepers says that the anti-creeper must be substantial enough to stand driving to place, without danger of breaking. There are many forms of anti-creepers which do not require to be driven in place.

The President:—The meaning of the Committee is that if their application should require driving they should be strong enough to withstand it.

Mr. Lindsay:—With relation to the paragraph that "the anti-creeper must not loosen when in place, or sufficiently to slip when the rail slacks back," I have recently conducted in a rather imperfect way a test on a testing machine of some anti-creepers, and it is very curious to note their action. I took a short piece of rail and attached the anti-creeper to it, stood the rail on its end, and pushed the anti-creeper to see what happened. Some of the anti-creepers slipped before they became entirely displaced, and some slipped and held on for a certain length of time, and then gave way, and others broke. The strongest sustained a load of over 9,000 lbs. before yielding. I think it would be profitable to carry out a series of tests.

The idea of the Committee in this feature is to avoid the displacement, or the rendering of the anti-creeper inoperative, when the rail again resumes its forward motion. If the anti-creeper slips, and stays on the rail, let it slip, so long as it holds its position, and when the rail goes forward again, the creeper clamps on to the base of the rail and retards the movement of the rail or carries the tie along and it is all right. I think the clause should read, "They must not loosen when in place, sufficiently to render the anti-creeper inoperative when the rail slacks back."

The President:—The Committee will accept that.

Mr. Jenkins:—I move the adoption of the general requirements to be met in the design and manufacture of anti-creepers, for publication in the Manual.

(Motion carried.)

Mr. Edwin F. Wendt (Pittsburgh & Lake Erie):—I want to make a few remarks on the question of the Economics of Track Labor, referred to in this report. A number of the committees have begun the study of economics. This work grows out of the address of Mr. Loree, submitted at the last banquet, which showed that about 55 per cent. of all of the expenses of a railroad consisted of the cost of labor. The object of our Association is the advancement of knowledge pertaining to the

scientific and economic maintenance of railways. I submit that we have done well to take up these scientific studies which relate to economics, and the beginning of this work marks an epoch in the history of our Association.

The relation of the cost of labor to the gross revenue of all the railroads in America has risen, as shown by the figures of the Interstate Commerce Commission. During the past 20 years, wages to gross revenue have risen from 37.7 to 41.9 per cent. During the same period the ton-mile rate, which represents the amount of money the railroad company receives from the public, has declined from 9.3 mills to 7.5 mills, and during the same period the relation of dividends and interest to gross has declined from 28.3 to 24.2 per cent. It is, therefore, apparent that every effort should be made to bring about such economics in labor as are possible.

The Track Committee has outlined on page 108 a program for the systematic and scientific study of this question of economics, and I think that program should be commended to a number of other committees of our Association. Its excellence is beyond question. In this connection I desire to submit with my remarks a table which shows the relation of wages to gross revenue, etc., such as I have described.

In our railroad industry there are three interests entitled to a hearing, the capitalist, the wage-earner and the people who use the roads.

To show how each of these three interested classes has fared for some time past, here are the percentages of total gross earnings devoted to wages and to interest and dividend payments. How the third party of the contract, the public, as typified by the shipper, has fared, can be seen from the average rate per ton per mile:

	Per Cent. Wages to Gross.	Per Cent. Dividends and Interest to Gross.	Ton-Mile Rate.
1911.....	41.90%*	24.27%*	0.750*
1910.....	40.43	23.47	0.753
1909.....	40.03	24.33	0.760
1907.....	40.47	20.99	0.759
1905.....	39.36	23.84	0.766
1903.....	38.82	24.47	0.763
1900.....	37.99	25.74	0.729
1895.....	40.78	30.17	0.840
1890.....	37.71	28.37	0.930

* Estimated.

Since 1890 wages have risen 11.1 per cent., as compared with gross earnings, while dividend and interest payments taken together, notwithstanding the rise of recent years, show a net decline of 14.5 per cent. The general tendency has been to devote a decreasing portion of gross earnings to payments to the capitalist, and an increasing portion to wages.

Mr. Lindsay:—The Committee on Accounts was assigned the question of the preparation of blanks, etc., for the ascertaining of *unit costs,*

and I will have something to say on that report when the matter comes up, but the Committee on Track proposes to study right along the same line, a system of reports to measure the efficiency of gangs for various kinds of work, and establish a system of unit costs, and a system of work cards, etc. It seems to me there would be some conflict between the two committees, but undoubtedly the matter can be straightened out by the Board of Direction.

The President:—Are there any further remarks relating to the report of the Committee on Track.

Mr. Lindsay:—I ask the Committee to study the question of crossovers. It is a large subject very much in evidence, and we are told that the recommendations of this Committee are all wrong, and that we must have a No. 20 crossover, to be entirely safe, in order to operate a railroad safely. The Committee has considered nothing longer than No. 16 as necessary, but one Public Service Commission has gone on record as saying it is entirely safe to run at the normal speed incident to everyday operation through a No. 20 crossover.

I hope the Committee in studying this question will give attention to the matter of curvature at the switch angle, I figured roughly with an engine of 17-ft. wheel base, on a 15-ft. switchpoint, with a spread at the heel of 6 in., the curvature is equivalent to 22 degrees and 35 minutes; with a 20-ft. switchpoint it is 16 degrees and 15 minutes; with a 30-ft. switchpoint it is 13 degrees and 6 minutes; assuming the rigid wheel base of a locomotive, as including the distance from the forward pony truck to the rear driver as 26 ft.; with a 15-ft. switchpoint, the curvature is 14 degrees 34 minutes; with a 20-ft. switchpoint 10 degrees 55 minutes, and with a 30-ft. switchpoint 8 degrees 30 minutes; assuming the rigid wheel base as 34.66, with a 15-ft. switchpoint the curvature would be 11 degrees 2 minutes; with a 20-ft. switchpoint the curvature would be 8 degrees 55 minutes; with a 30-ft. switchpoint the curvature would be 6 degrees and 37 minutes, the question is: How fast is it safe to go over the switchpoint, regardless of the curvature of the turnout, and go by that switchpoint, without any elevation, at normal speed?

Mr. Jenkins:—The Committee has gone ahead with its work since the submission of its report, and has prepared designs for crossovers, which it will submit next year; the Committee has also undertaken to find out the relation of speed to turnout radius and the relation of speed to the switch angle, and we have made some progress along that line.

The President:—The Association wishes to thank this Committee for the labor it has performed, and they are relieved.

DISCUSSION ON CONSERVATION OF NATURAL RESOURCES.

(For Report, see pp. 133-143.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON CONSERVATION OF NATURAL RESOURCES.

GEO. W. ANDREWS.
J. L. CAMPBELL.
L. A. DOWNS.
C. H. FISK.
WILLIAM MCNAB.
S. N. WILLIAMS.
R. C. YOUNG.

The President:—The report of the Committee on Conservation of Natural Resources will be presented by Mr. William McNab, the Chairman.

Mr. William McNab (Grand Trunk):—This report on conservation may be accepted as one of progress. The aim of the Committee is well known to the members. We have endeavored to keep in touch with the National organizations, State organizations, Provincial organizations and thereby to collect certain data, figures, statistics, etc., which will be of interest to railways.

We have not accomplished a great deal as yet, but have under consideration the furthering of more intimate relations between the Committee and the chief officials of the organizations to which reference has been made, so that we can perhaps present to them, as opportunity offers, our desires as to how certain results might be produced in their investigations, which would be directly interesting to the railways, and then to collect these matters and lay them before the Association.

In the meantime, therefore, the report which is found in this Bulletin may be looked upon as one of progress and the Committee would be very glad to receive suggestions from any of the members present, if they have anything special, in the way of line of investigation they would like to put forward.

Mr. L. A. Downs (Illinois Central):—I have not been clear in my mind as to why this Association fosters the Committee on Conservation of Natural Resources. We are an association of builders. Unfortunately in this country, at the present time, conservation is getting badly mixed up with the differences between the "interests" and the Common People. I was in Alaska this past summer, and Alaska is dead. It is dead because of the conservation policy in this country, that is, those that are laid down by those great conservators, Pinchot, Garfield, Roosevelt and others, who are holding the resources of the country for future generations under the guise of keeping the "interests" away from it.

The Copper River & Northwestern Railroad operates 194 miles of road in Alaska. They had been burning coal in their locomotives until about a year ago, importing the coal from Canada and paying a duty on

it, while the hills of Alaska are full of coal, but the laws of the United States prevented them from getting the coal out of the hills. This road is now burning oil in its locomotives because oil is cheaper than coal, which they buy in Canada and on which they pay a duty.

The first idea I ever heard of conservation was of a Scotchman who figured that if he could grow some trees that were nice, long, slender fellows they would do for the masts of sailing vessels and steamships, and so he provided in his will that at the expiration of 100 years the trees could be sold, but that they should be kept growing until the end of that time. The 100 years passed away and when the trees could be used for masts, it was found that the masts of vessels were being made of steel, and they did not require the trees.

I think that God, in his Almighty Wisdom, never intended when he placed us on this Continent that we would run out of anything—while some things have become somewhat scarcer, I question whether you can recall anything which we have run out of entirely.

It seems to me if we could have a committee to prevent waste, a committee to prevent forest fires and other things, rather than a committee of conservation who hold the opinions of those great conservators in this country that seem to array the "interests" against the Common People, then it would be all right.

I have read this report and the Canadian rules on locomotives read a good deal like the full-crew bill before the legislature in Iowa, that is, they desire the railroads to do this, that and the other thing, and while I think probably it is all right to prevent forest fires, I do not think we should hold the natural resources of this country up as we are now holding up the great coal lands in Alaska for the benefit of a few generations, and when the time comes to use the coal we will find that Edison or his successors will be giving us fuel out of the air and our coal will all be in the Alaska hills.

I believe this is a question which the Board of Direction should go into pretty deeply, and find out if we, as a body of men who are railroad builders, and a body of men who build up and tear down, who go through the forests and into the hills, and who go deep into tunnels, should concern ourselves with problems of the conservation of the natural resources of the country.

Prof. S. N. Williams (Cornell College) :—We have had a great many fine things presented to us from the Dominion of Canada, and I wish to express hearty thanks to our highly esteemed brother, Mr. McNab, for what his country has done for us during several years past in the way of improved ideas and new things. As I look through this report, it seems one of the most important subjects that can be presented, and I thank the Committee for having given us a statement of what Canada has been doing towards preventing forest fires along railways, also in the direction of reforestation. Unfortunately in this country we have suffered during the past four or five years to the extent of millions of dollars in forest fires, which have been developed partially by railways. I have

had some painful experiences and observations in that direction myself. I know that in some cases railways have not taken precautions to prevent forest fires, and have not provided means for their extinguishment, after they have started along their lines, which they should have done. I think if you have paid any attention to the situation in this country for the last five years you will be convinced that this is a very important subject, and that the matter of reforestation, which has been considered so important in Europe and has been developed to a limited extent in our own country, is one of the most practical matters we can consider. When railway companies set aside large tracts of ground in order to cultivate trees so that they may produce their own ties, as is being done in this country, it is an important subject to be continued.

My own State, Iowa, was referred to a few minutes since, and I do not know whether it was intended as a matter of amusement or not, but we are trying there to prevent the introduction of some things we do not consider for our best good, and do not care to have them imported from Illinois or other states, if not in harmony with our ideas of the best good of the people. We are trying to regulate various matters, hence we feel decidedly progressive. We do not wish to be interfered with by other states, and want to develop any new ideas given to us, so I trust the railways will not take it amiss if we try to regulate the hours of labor, etc., to protect the interests of the railway employes. I want to express my high appreciation of the report which was presented by this Committee.

Mr. George W. Andrews (Baltimore & Ohio):—I want to say that I heartily agree with the sentiments expressed by the last speaker, especially that portion referring to what Canada has given us. I will go further—I hope some day that Canada will give us itself. Mr. Downs has said that God Almighty has blessed us with many things. It is very true that He has blessed us, but we have not shown our appreciation. The gross waste of timber in this country has been outrageous. I can recall to mind, when I was a boy, the Allegheny Mountains were covered with a forest. Millions of feet of hemlock were cut and denuded for the bark alone, while the timber was left to rot. Many of the trunks are still there. You can pass over stretches in the Allegheny Mountains to-day and see millions of feet of timber, in the original log, from which the bark was taken, and the trees lying there to rot. Much of this timber lying in the mountains has caused destructive forest fires.

If this Association is not the proper body to build up the conservation of natural resources, then I am at a loss to know which is. There are probably no corporations in the world to-day that are suffering more on account of the gross waste of timber than the railroads, and many important railroad systems in this country have realized that fact and they have gone into the planting of trees on an extensive scale and many others are contemplating doing it.

It has been remarked that there is no reason why we should take care of future generations. I think that is one of our bounden duties.

Many of us have children and grandchildren. I have a grandson and I expect that some day he will be a Chief Engineer of a railroad, and I want to help conserve the natural resources of this country to help him.

Mr. McNab:—I have to take issue with Mr. Downs in one remark he made—I do not believe that the man who planted the trees for the purpose of masts, from which the advantage of the planting was to be derived at a period 100 years hence, was a Scotchman!

Now, gentlemen, this question of conservation is one concerning which we must divorce from our minds the idea that it has anything to do with any one country. The mere fact of the Canadian section being somewhat lengthily spread out in the report is owing to force of circumstances, which are explained in the preamble of the report. Whatever interests Canada in the way of conservation interests the United States and vice-versa. We are really working for the conservation of the resources of the one continent.

I accept the remarks of Mr. Downs with good nature. Hitherto this Committee has taken the material on conservation available in the several associations and put it into a hopper and then run it through the spout. That is practically all that has been done so far.

The most important feature of conservation is the prevention of waste, and as I said at the outset, we have not been extremely active in making suggestions to any of these associations, but we have that matter under consideration at the present time. The Board of Direction in its wisdom appointed this Committee, and if this Association thinks we can by our investigations lay before our railway managers something which will help them along the lines of conservation we will be very glad to continue the work. The report is simply one of information, at the present time.

Mr. J. L. Campbell (El Paso Southwestern):—I think it would be well if we did not get away from what I understand to be the fundamental purpose of conservation. I personally am not entirely in accord with the ideas of conservation as they have been practiced to date in some sections of the country. I think there is probably something in what Mr. Downs has said in regard to the locomotives in Alaska finding it more economical to use crude oil rather than coal, because they cannot get the coal. However, I think such are features that do not necessarily touch the principle of conservation at all.

I understand that primarily conservation is intended to provide for the efficient and economical use of our resources, saving those parts of our resources which we do not need for the present, for future generations, and I believe we can all agree on that feature of conservation.

As Engineers, I believe it is our special duty to see that the resources of the country which we handle are efficiently and economically used by us, and it does seem to me that this is a proper committee for this Association to maintain and continue, and that we are touching one of the great fundamentals of our civilization when we take up the consideration of this very important subject. I think we can take it

for granted, inasmuch as this conservation idea is receiving such universal attention, that there is a great deal in it. I think we are on the right track and we should continue as we have begun.

Mr. R. C. Young (Lake Superior & Ishpeming):—The railways which I represent are located in the timber districts of Michigan, and I have been working in the timber districts for a number of years. I agree with one of the speakers that a very large amount of the timber has been wasted in the timber districts; the gentleman who referred to the denuding of the hemlock trees simply to get the bark of the trees presented a case in point. The railroads are interested in conservation in many ways. In the first place, a great many of our railroads are dependent more or less for their business on the products of the forest and the products of the mines. I do not think it is our province to conserve these products to such an extent that they cannot be used, but to see to it that they are conserved to such an extent that they can be used at the right time, and the portions not used now will be conserved for use by future generations.

In the upper peninsula of Michigan we have just started to use hardwood timber, the part which is marketable is being used and the rest of it is being wasted. There are some industries which use the things which are by-products in other industries, and as a railroad corporation it is our business in that part of the country to see that these by-products are used so that we can have the transportation of the primary products and the by-products to supply our roads with freight traffic in the future.

The State of Michigan is laying the burden of forest fires largely upon the railroads. We have been obliged to make use of our sectionmen in dry times to watch the right-of-way to put out fires and see that they do not spread into the forests. The burden of the proof generally lies on the railroad companies as to the damage to the forest. If there is no other cause apparent, the railroads are blamed for fires which as a matter of fact they are not to blame for. On the roads with which I am connected we have adopted a system of fire reports, every fire that occurs in the vicinity of the railroad is reported, and we endeavor to ascertain what the cause is and what damage has been done, and we file this information for general use and the protection of the company. I think that the railroads are very largely interested in this matter of forest fires.

It was my privilege to attend the National Conservation Congress and we found that they are aiming to extend their work beyond the conservation of materials to the conservation of the resources of men. It seems to me that is an interesting subject that we are concerned in. I think there is a large field of work before this Committee, in various parts of the United States and Canada, which will be of much practical value to the railroad companies.

Mr. L. A. Downs:—I think, after all, that we are nearly together on this. My previous argument was based on conservation as laid

down by the great conservators of this country, but the ideas expressed by the gentlemen who have taken part in the discussion this morning are much more moderate. I wish to say, however, with regard to the conservation of timber and its use for ties on the railroads of this country, we used to cut the heart out of a tree to get a tie that would last seven years, and we used to waste the sap. Now we are using the wood with the sap and getting a tie that will last 12 years, or perhaps more. The most flimsy element in the construction of a railroad is the tie. Think of the enormous sums of money that we have to spend on railroad ties, and consider the fact that these ties only last on an average seven years, and then think of the vast undertaking of tearing up the track and building it over again. I believe we must build our track with something besides timber—the use of wood for ties must be superseded by a more durable material—and I do not think we are going to help matters by holding for the future but must get something that will take care of the most flimsy thing in railroad construction, which is cross-ties. The Committee on Ties, of which I have the honor to be a member, will have to develop something to take the place of the wooden tie.

I agree with all that has been said regarding the curtailment of waste. I believe with the other speakers that the Committee can do a great deal of valuable work in that direction. I lived in Mississippi and I saw great numbers of trees which had been cut down and allowed to rot, and it is a great wrong to waste material in that way. We are going to be taken care of in the future. What would we do for messenger boys, if it were not for the telephone? One thing takes the place of another all the time, and we will not run out of the things which we need.

As I have said before, the great work seems to be the conservation of timber, and that the railroads are mostly interested in the subject because of the use of timber for ties. The wooden tie is a dead one, and we must get something else to take the place of the wooden tie, and I believe that the future will take care of itself in regard to providing a substitute for the wooden tie in our railroad tracks.

Prof. Williams:—Supplementing the statement of Mr. Young, I will say that one of our government departments has recently made the statement that the annual waste of resinous products in the United States is estimated at 15,000,000 cords, and if made up into paper-making products in the shape of wood pulp would be worth $300,000,000. I think that is a sufficient commentary on the waste practiced at the present time.

The Chicago & Northwestern, and I believe also the Pere Marquette, sometime since issued a circular letter to all the agents of these railways advising them that they must be careful in the use of the stub ends of pencils, also in the use of pens, and all the other office stationery, also giving an estimate as to the present waste in the use of these articles,

and stating the amount which might be saved annually to the company by the economical use of these things. The roads also sent inspectors to explain to the various agents the ideas of the officials in regard to such matters.

You will pardon me if I say that the conservation of resources is one of my hobbies. I tell my students that they must conserve time, money, energy, space and material. We all know how important it is that everything else should be conserved as well as these natural resources in the way of timber. The magnitude of the subject has begun to dawn on the country, just as other matters concerning sanitation and prevention of disease, which affect our existence, both as individuals and as a nation.

Mr. George W. Andrews:—Mr. Downs laid special stress on what the Almighty in His wisdom would do for us. I think every man here knows that the Almighty helps a man most who helps himself, and if we do not help ourselves and rely on the Almighty, we will unquestionably come out at the little end of the horn.

Mr. C. H. Fisk (Consulting Engineer):—Mr. Downs, I think, has been won over to the idea of the Association having a Conservation Committee. We of the Committee on Conservation feel it is one of the most important committees which the Association has. We are builders, as Mr. Downs says, but unless we conserve our building material, what shall we have to build with? This Committee does not foster nor protect the Alaskan coal fields for the Seven Sutherland Sisters or Brothers. We are looking into the iron and steel conservation. The fuel oil situation we think is most important. The consumption of oil is increasing at an alarming rate, and inversely the production is decreasing. We are depending on our oil to a great extent for our fuel in the Southern States, and it is coming to such a pass now that some of the roads are beginning to go back to coal.

In Canada we have the peat fields which are becoming smaller all the time and they have to be looked into.

We feel that this Committee has started within the last two years in the right direction, to conserve everything pertaining to railroads. It is not within our view to go into Alaska to conserve the coal fields there, or to conserve the human race, as Prof. Williams has suggested, but to co-operate with all national conservation movements in conserving everything that pertains to our line of work.

Mr. Young and I attended the National Conservation Congress held in Indianapolis last fall and received a great deal of information, and a great deal of information which was very appalling in the statistics and data, showing how the production of oil was decreasing, how its consumption was increasing, and the enormous waste in the production of coal.

It is our duty to try as much as we can to reduce the waste in the production of the things in which we are vitally interested and we feel that this Committee should not only be continued as an active

working committee of the Association, but that the information for which the Committee asks from the railroads should be given cheerfully and promptly, and what information we send to the members of the Association should be carefully studied and transmitted to the heads of the railroads in which we are interested. A great deal of the information sent out by the National Conservation Congress is neglected and thrown aside when, as a matter of fact, to us who know what that information means, we feel it should be printed in box-car letters; and we ask when we send you information on this subject that you not only read it yourselves, but pass it to the heads of your roads, and ask them to think about it and help you and us in the conservation of natural resources.

Mr. McNab:—I move that the report presented by the Committee on Conservation of Natural Resources be received as a progress report.

The President:—If there is no objection, that will be accepted as the sense of the meeting. The Committee is relieved, with the thanks of the Association.

DISCUSSION ON BALLAST.

(For Report, see pp. 144-168.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON BALLAST.

MAURICE COBURN.	S. A. JORDAN.
C. C. COOK.	J. R. LEIGHTY.
E. A. HADLEY.	S. B. RICE.
H. E. HALE.	R. C. WHITE.
W. K. HATT.	S. N. WILLIAMS.

The President:—The report of the Committee on Ballast will be presented by the Chairman, Mr. H. E. Hale.

Mr. H. E. Hale (Missouri Pacific):—The Committee was asked as one of the questions submitted to it to report on proper depth of ballast of various kinds to insure uniform distribution of loads on roadway, conferring with Committee on Roadway.

The Committee wishes to recommend the test given on page 145. The Committee searched for reports of tests in periodicals without much success, not getting anything more than that we had already presented to the Association, and to get further information in line with the request from the Association we propose the test shown on page 145.

(Mr. Hale then read the proposed test, by paragraphs, as given on page 145.)

Mr. Hale:—The conclusion which we offer in connection with these proposed tests is shown at the top of page 146, and reads as follows:

"Your Committee recommends that the above test be made under the direction and supervision of the Ballast Committee, and that the same be financed by the Association or some railroad or railroads. The location for the test to be arranged for by the Committee with a railroad that would be willing to have this test made in their main tracks under heavy, regular traffic."

The President:—This is a progress report, and is offered for information. The recommendation that funds be appropriated is a matter that will be handled by the Directors and we have reason to believe that it can be arranged in some way. The subject-matter of the several numbered paragraphs that have been referred to is a matter of information particularly to the railroad which will permit of the tests being made on their tracks, and we hope that one or more railroads will come forward and permit this, provided that funds are later secured in some way, and with this explanation the Chair thinks the convention will understand that this report is submitted as a matter of information as to the methods of procedure that this Committee proposes to follow.

Mr. John R. Leighty (Missouri Pacific):—I would call attention to the very short distances over which the various depths of ballast pro-

posed is to extend. We all know that a bad spot in a track will grow like a bad spot anywhere else, and influences the condition of adjacent track. It seems to me if you take two rail lengths of track under one condition and compare them with the adjacent two rail lengths, such a comparison will not lead to any definite information. The condition of one section of two rail lengths will very materially influence the conditions that will be found on the adjacent two rail lengths, and it would be my suggestion in carrying out this experiment that the sections of track be made sufficiently long to make sure that the conditions existing on one section of track will not influence the conditions existing on an adjacent section of track, so that you will get a comparison which will really amount to something.

Mr. Hale:—The next subject assigned to the Committee was to continue the study of physical tests of stone for ballast.

The Committee made further investigation as to the physical test of stone for ballast, but was unable to find anything of interest which the Committee thought the Association would be interested in. The Committee found one paper read at the Sixth Congress of the International Society for Testing Materials held in New York last September, which copied the tables of last year's Ballast report, and we could not get much additional information from that source.

In considering this subject the Committee feels that the recommended physical tests of stone for ballast are not well enough understood to be incorporated into specifications as yet, but they recommend for incorporation in the Manual the following note on page 146:

Note.—Attention is called to the physical tests of stone for ballast printed in the Manual, page 47, which are recommended as a guide, in connection with these specifications.

The President:—Unless there is objection this will be considered as approved.

Mr. Hale:—After further consideration of the physical tests which are recommended, the Committee wishes to recommend the following change:

"It is recommended that the following be used for physical tests of stone ballast. *Other things being equal, the maximum or minimum results as indicated will govern in selecting stone for ballast:*

(a) Weight per cubic foot—*Maximum.*
(b) Water absorption in pounds per cubic foot—*Minimum.*
(c) Per cent. of wear—*Minimum.*
(d) Hardness—*Maximum.*
(e) Toughness—*Maximum.*
(f) Cementing value—*Minimum.*
(g) Compression test—*Maximum.*

"For the description of the physical tests of stone for ballast as recommended by the Association and full instructions as to how the samples should be obtained and shipped to the government for test (test made free of charge by the United States Government), see Proceed-

ings of the American Railway Engineering Association, Vol. 11, Part 2. pp. 910-914, and report of Ballast Committee of 1912. If blue prints of the machine used in making the tests are desired, they can be obtained from the Department of Agriculture, United States Government, Washington, D. C."

Prof. S. N. Williams (Cornell College) :—I think it is due the Chairman of the Committee to have it stated that he made an effort to secure funds during the year from different railroad companies for prosecuting these experiments, but was not successful in securing enough to carry on the experiments, so it would seem in order to express our appreciation as a Committee of the help given us, also other committees, by some of the great railway systems of the country, notably the New York Central, the Pennsylvania, the Baltimore & Ohio and the Santa Fe. If there are any others who have helped us I would be glad to have them also mentioned. These railway systems have not only shown commendable progress in the way of the development of their railway lines, and in advancing the progress of the railway service of the country as a whole, but they have also been very generous in helping out committees, and it is due these companies that we should express our appreciation of their generosity, because this is the only way in which we can secure a sufficient amount of help in various directions to carry out these investigations, which are expensive, and the expense must be borne by someone.

The President:—Mr. Jordan, can you give us any information on the subject of these proposed tests?

Mr. S. A. Jordan (Baltimore & Ohio) :—I will say to the convention that our investigation this year discloses comparatively nothing new relative to the physical test of stone for ballast.

Mr. Hale:—There is one subject that comes up pretty nearly every year and that is the size of stone ballast, which is closely allied to the physical test. The Committee was fortunate enough to find a record of a test made in 1903 on the Pennsylvania Railroad, and while it was made some time ago, it gives some interesting information. A resumé of this test appears on page 147. It shows the first cost, and also the cost of maintenance, of putting in stone ballast. The test was carried on for a period of about three years, and the test showed that the larger size stone costs less to put in and less to maintain.

The President:—If there is no objection it will be understood that the report of the Committee under the heading, "Continue study of physical tests of stone for ballast," will be accepted as a progress report.

Mr. Hale:—The next item which the Committee had referred to it was to continue its investigation on gravel ballast and recommend methods of grading different qualities.

Last year your Committee obtained from various railroads a report of the percentage of sand and dust in their ballast and they tabulated this information and presented it to the Association, but the results were so erratic that little information could be drawn from it. One of the reasons for this, your Committee found, was that the method of testing

was not uniform. Some of the railroads weighed the ballast to determine the percentage of sand and dust, others measured it by volume and others had different methods of calculating the percentage. The Committee felt it was of the first importance to have a uniform method of measuring or testing the sand in ballast and with that end in view we have recommended the following method, to be printed in the Manual:

"Method of testing quality of gravel for ballast: (1) The size of the sample to be tested should be approximately one cubic foot.

"(2) Five average samples of about one cubic foot each should be selected from various parts of the pit which is to be tested. The five samples should then be thoroughly mixed and about one cubic foot of the mixture selected for testing.

"(3) To separate the gravel from the sand and dust use a No. ten (10) screen, ten meshes to the inch), made of No. 24 wire (B. & S. gage); to separate the sand from the dust use a No. fifty (50) screen (fifty meshes to the inch), made of No. 31 wire (B. & S. gage).

"(4) Measure the percentage of gravel, sand and dust taken from the sample by volume, giving the percentage of each ingredient, compared to the volume of the sum of the ingredients, as follows:

$$\text{Per cent. of sand} = \frac{S}{G + S + D}$$

Where S = Volume of sand.
G = Volume of gravel.
D = Volume of dust.

"(5) When sample is shipped for test it should be carefully and securely marked with name and location of the pit from which it was taken."

Mr. C. C. Cook (Baltimore & Ohio):—That first "S" is confusing. Should it not mean "sum?"

Mr. Hale:—"S" means volume of sand.

Mr. Cook:—In both cases?

Mr. Hale:—The reason the Committee had for adopting this method was because the method now prescribed in the Manual of dividing the volume of sand by the volume of the original bulk results in getting the sum of the per cents. equal to more than 100—per cent. of sand, plus per cent. of gravel, plus per cent. of dust would equal somewhere between 110 and 130, due to the fact that the voids are filled with part of the ingredients.

Your Committee considered several methods, among others the concrete mixture method, of mentioning the parts as 1, 3 and 6, as being desirable, but the use of the word "per cent." of sand in ballast is so common that the Committee did not wish to depart from it, but desired to give a form in which the percentage would be used, but in which the sum of the per cents. would equal 100, and for that reason we have adopted the method suggested.

Mr. E. A. Hadley (Missouri Pacific):—I note on page 150, if this formula is adopted, that it will change the wording in the Manual. Ballast is generally purchased by the cubic yard and generally the per cent. of sand in the ballast is specified, for instance, 35 per cent., which I understand to mean 35 per cent. of the original volume. It seems that in making their formula the Committee have omitted one of the component parts of the ballast, which is the voids, as without the voids the ballast will not properly serve its purpose, and should they add the voids in their formula they would still come out with 100 per cent. at the end. If the Committee's suggestion is adopted, it would add to the per cent. of sand in the ballast, and, as ordinarily accepted, it would amount to from 5 to 8 per cent., depending on the quality of the material. It seems to me in leaving out all consideration of the voids an omission has been made which should be corrected.

Mr. Hale:—The Committee considered that, but instead of making the sum of the per cents. of the ingredients equal to 100 per cent. by the old method (the method now printed in the Manual), taking into consideration the voids obtained, a percentage of voids of possibly 10 or 15 per cent., which is added to the percentage of other ingredients, the sum becomes 130 or 140 per cent. Your Committee investigated the methods of washing gravel by several of the gravel companies selling ballast by contract, and it found the method being used by the contractors similar to this method recommended by the Committee.

The Committee is not altogether satisfied with this formula in one sense, but it is by far the best that has been suggested. As to the present method printed in the Manual, your Committee is absolutely unanimous in recommending that it be abandoned, and furthermore, they are unanimous in recommending this formula as being the most satisfactory, where it is being used in practice by contractors and others.

Mr. Maurice Coburn (Vandalia Railroad):—I would like to ask if the Committee considered the question of measuring by weight?

Mr. Hale:—Your Committee has considered that, and the variation due to moisture was so great that they abandoned it. Several of the railroads, the Burlington and the Santa Fe, made quite a number of extensive tests by weight which were not satisfactory.

Mr. Hadley:—I cannot agree with the Chairman of the Committee that the use of the per cent. of voids in the ballast would go to make 140 per cent., as the per cent. of voids properly used is a minus quantity. The sand runs into the voids in the gravel, partially filling them, the same as the dust runs into the voids in the sand, and if properly used, the per cent. would equal 100.

The President:—There is no motion before the convention. We will proceed.

Mr. Hale:—With reference to the fifth paragraph, some of these clauses seem rather unnecessary possibly. The Committee has had so much trouble in getting samples properly tested that they found every clause here very important. I would like to make a motion that the

above method of testing quality of gravel for ballast be accepted and put in the Manual.

(Motion carried.)

The President:—This matter will be published in the Manual as recommended practice.

Mr. Hale:—The carrying of this motion automatically cancels one paragraph of the Manual, on page 150: "The above will necessitate the cancelling of the following paragraph, on page 49 of the Manual."

The President:—If there is no objection, this will be done.

Mr. Hale:—Your Committee would like to recommend the following subjects for investigation next year—

The President:—The Board will take cognizance of that. If there is no further discussion on this subject of ballast, the Committee will be relieved with the thanks of the convention. They have given us very valuable information in this report and in the appendices. The Chairman of the Committee states that he has one more point to present.

Mr. Hale:—Mr. Rice, of the Richmond, Fredericksburg & Potomac, has some very interesting figures on the cost of washing gravel ballast, which, I believe, the Association will be interested in, as a good deal of this work is going on along the Richmond, Fredericksburg & Potomac.

Mr. S. B. Rice (Richmond, Fredericksburg & Potomac):—We are operating a ballast pit and washing plant on the Richmond, Fredericksburg & Potomac and Washington Southern Railway, known as the Richmond-Washington Line. This pit is located about the center of the line, that is, fifty-seven miles from Richmond and fifty-seven miles from Washington. We first started to handle this ballast as pit-run material and had good results from same. We afterwards concluded that we could get better track by the washing of gravel, and for this purpose a washer was installed and was started in November, 1908. Since that time the entire line has been reballasted with washed gravel. The average cost of loading per cubic yard was 8.95 cents, washing 11.34 cents, hauling 11.11 cents, placing in track 26.15 cents; or a total cost of 57.55 cents per cubic yard of finished track. These figures represent the average cost as near as could be gotten for reballasting the entire line.

A Member:—What was the average haul?

Mr. Rice:—The extreme haul was fifty-seven miles. There were times when the cost of loading was as low as 6 cents per cubic yard. The pit varied in depth from 6 ft. to 22 ft., and, of course, the deeper the cut the less cost of loading. The long and short hauls made a difference in cost per cubic yard in the haul. These figures were made up after three years' work, or after the delivery of about 400,000 cubic yards. The track that was ballasted in 1908 is in good condition to-day. Of course, this track shows a little dirt from trains, but we have not had any bad or slop joints. With regard to the cost of maintenance: for the months of December, 1912, January and February of the present year we had an average labor cost of $19.00 per mile per month, or an average cost of 63 cents per mile per day. We have twenty-four through passenger trains over our line per day, as we are handling trains for both

the Atlantic Coast Line and Seaboard Air Line. Some of these trains are very heavy, that is, they consist of ten and twelve cars per train. We also have an average of twenty-two freight trains per day. The average tonnage of these trains is between 700 and 800 tons per train. We feel as if we had as good track with the washed ballast as could be gotten with crushed stone of any character.

Mr. R. C. White (Missouri Pacific):—I would like to draw the Committee's attention to the table on pp. 148 and 152. In this table they give the percentages of gravel, sand and dust, but no reference is made to per cent. of voids in screened gravel. It strikes me that the percentage of voids in screened gravel is a very important factor in determining the amount of sand permissible in gravel ballast, and I feel that this should be given consideration. I would also suggest to the Committee that they discriminate between voids in ballast as a unit and percentage of voids in screened gravel as a unit, so as not to get the two confused.

Mr. Hale:—Your Committee made last year quite a number of tests of the voids in gravel and it was the opinion of the Committee that it was not of sufficient value to present to the Association. In other words, while it was theoretically interesting, it was of no practical value to the Association, and we therefore did not include it in the report.

Prof. W. K. Hatt (Purdue University):—On page 149 what is given is the ratio and not per cent. Should not that be corrected?

Mr. Hadley:—That is exactly my contention. I think the term per cent. is a misnomer on the basis in which the Committee has attempted to write the per cent. of dust or sand in gravel ballast.

Mr. Hale:—The Committee will accept that suggestion, making it per cent. instead of ratio. It will be necessary to multiply the formula by 100 to indicate the per cent.

The Committee prefers to retain the term "per cent." because it is in common use by contractors and others. If it were not for that reason, the Committee would prefer to recommend that the proportion be stated in "parts" as in concrete mixture, "1: 3: 6," but on account of the term "per cent." being in common use the Committee prefers to retain it, and after discussing the various methods this was considered most practical and desirable.

Mr. R. C. White:—Referring again to the per cent. of voids on page 148, it reads, "the portion which would not pass through the 10-mesh sieve was calculated as gravel." That will hold back a good-sized rock. If we did not have a table showing the per cent. of voids in this screened gravel, we would be at a loss to determine the size of gravel permissible. The per cent. of the voids will aid us in determining the size of the gravel, and in a measure *determine* proportion of per cent. of sand permissible.

Mr. Hale:—That point came up before the Committee and is covered in the definition of "gravel" in the Manual, which is the material which will pass through a 2½-in. ring, but was retained on a No. 10 screen.

The President:—If there are no further questions or remarks, the Committee will be relieved, with the thanks of the convention.

DISCUSSION ON BUILDINGS.

(For Report, see pp. 839-880.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON BUILDINGS.

G. D. Brooke. C. E. Lindsay.
Maurice Coburn. S. N. Williams.

The President:—Mr. Maurice Coburn, Chairman of the Committee on Buildings, will present the report of that Committee.

Mr. Maurice Coburn (Vandalia Railroad):—The Committee had two subjects this year, on which work was done, the continuation of the work on roofing, and a report on freight house floors. We would like first to consider the report on freight house floors, page 879. In going over this report and attempting to make conclusions for the Manual, it was decided that we would ask that this entire report on freight house floors be printed in the Manual.

The President:—This matter has been before the members of the Association for some time. Unless it is specially requested that the paragraphs be read, it will be considered as before us for acceptance. Is there any objection to that method of procedure? We are ready to discuss any particular feature of the matter on pp. 879 and 880.

Mr. C. E. Lindsay (New York Central & Hudson River):—I would like to call attention to the first paragraph, on page 879, and to a new development that has given rise to some question in our minds as to the permissible load per square foot, and that is the use of electric trucks in freight houses, transfer stations, etc., and the heavy concentrated loads that will result therefrom. We have a new freight house that was designed for 250 pounds loading per square foot, and since then we have adopted the electric truck, with very heavy loads. I do not advocate increasing that amount now, but I call your attention to what is coming so that we may prepare for it.

Mr. Coburn:—The Committee will be pleased to insert in this report a paragraph stating that where there is any possibility of using these trucks that they should be considered. It seems to me that should be a part of this report.

Prof. S. N. Williams (Cornell College):—I would like to inquire if Mr. Lindsay has any definite amount to suggest instead of 250 pounds per square foot?

The President:—The Committee will investigate that during the year and bring it up later.

Mr. Coburn:—I move that this report, with the change suggested by Mr. Lindsay, be printed in the Manual.

(Motion seconded and carried.)

Mr. Coburn:—Referring to the discussion on roofing, the Committee will say they have combined the reports printed during the two

previous years. We have gone over the reports in detail and have made minor changes at various points. We have succeeded this year in presenting a specification for coal tar pitch for roofing purposes. We do not feel that we know enough about this subject to recommend its adoption by this Association, but it has been adopted by the United States government, and we feel that it is the best specification that can be had at this time. We have endeavored particularly to fill out some of the latter parts of the original report on the miscellaneous roofings and to bring the entire matter up to date. We would like particularly to call your attention to the few remarks on pp. 864 and 865 with reference to corrosion, under iron and steel roofing. This subject has been assigned, as I understand it, to the Committee on Iron and Steel Structures also, but your Committee felt that, due to its vital importance to our subject, that it was very necessary to say something about it. We are expecting to keep in touch with the Committee on Iron and Steel Structures, and see to it that there is no confusion or unnecessary duplication in the future. As we prepared this report, we desired to change the last conclusion previously printed in the Manual, and to add two more. On page 870 we put this in. After doing that, when we came to discuss the freight house floors and to abstract that for conclusions, we decided it was impossible to abstract that satisfactorily, so we have asked you to put all of that in the Manual, as it seemed to us that the report on roofings contained a great deal of matter which should go into the Manual, just as much as the material on floors. For that reason we printed that paragraph on page 869. This brings up the whole question as to what should go in the Manual, and we thought we would put it up to you in this way; that we would perhaps first ask that conclusions on page 870 be adopted, and if they are carried, we will ask that the Association give us the privilege of abstracting this report, subject to the approval of the Publication Committee. The report is pretty difficult to abstract. There are here and there a few paragraphs which should not go into the Manual. It seems like a good deal of material to put in, and we are a little in doubt as to what should be done about that. To start with, I move the adoption of the conclusions on page 870, as they stand.

The President:—If there be no objection that motion will be considered adopted, with the understanding that the Committee will co-operate with the Committee on Publications and the proper material will be put in the Manual. The Chairman of the Committee wishes the conclusions on page 870 adopted for publication in the Manual.

(Motion seconded and carried.)

Mr. Coburn:—I move that the Committee have the authority to abstract the report as it stands, for publication in the Manual, subject to the approval of the Publication Committee.

Mr. G. D. Brooke (Baltimore & Ohio):—It seems to me that that is contrary to the usual custom. I would offer an amendment that the Committee make these abstracts and present them in their next report.

The President:—Nearly all of it is to go in, and this method has been followed before. The idea is to get this matter in the next publication of the Manual. It is too voluminous to go over in detail. The members of the Association were asked to go over it before they came here and be prepared to criticise any point they wished to bring up. Those in favor of this special procedure, abstracting so much of this matter on Buildings as is thought desirable, on the part of this Committee in conjunction with the Publication Committee, and putting the balance in the Manual, will signify by saying aye.

(Motion carried.)

The President:—This is the end of the work of this Committee, and they are relieved with the thanks of the convention for their valuable work.

DISCUSSION ON WATER SERVICE.

(For Report, see pp. 881-912.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WATER SERVICE.

W. McC. Bond. Robert Ferriday. C. E. Lindsay.

The President:—The report of the Committee on Water Service will be presented by the Chairman, Mr. Robert Ferriday.

Mr. Robert Ferriday (Cleveland, Cincinnati, Chicago & St. Louis):—Your Committee was instructed to "report on the design and relative economy of track pans from an operating standpoint; report on the design of water stations using deep well pumps as source of supply; report on recent developments in pumping machinery."

(The Chairman read an abstract of the report.)

Mr. Ferriday:—Some question has come up with reference to conclusion and recommendation on pp. 911 and 912. The conclusion and recommendation are part of Mr. Vaughan's report to the New York Central Lines, and are not submitted by the Committee for the usual action. There seems to be some doubt in the minds of some as to whether these recommendations were recommendations by the Committee to the Association. This is just a paper by Mr. Vaughan, and the recommendations and conclusions are those presented by him to the New York Central Lines.

Referring to the second subject, we are going to try and see if we cannot investigate further on the subject of efficiency. The idea is quite prevalent that the old style of plunger pump is a very inefficient affair, but we have no definite data to prove that. The Committee also expect, in considering this subject this coming year, to see what we can do in the way of determining the efficiency of the ordinary piston pump, which is in common use all over the country, and also the efficiency of centrifugal pumps. We think we may have some interesting information on that subject. The fourth subject was not assigned by the Board, but is a standing sub-committee on water treatment. We are making a study of water softeners from an operating standpoint, which we hope to complete during the coming year, and we think it will be a valuable matter.

Last year we made a report on steel tanks, and at that time there was some desire to recommend some anti-corrosive steels, but we withdrew that from our report and recommended merely the use of open-hearth steel, but one member of the Committee was requested to handle the subject of anti-corrosive steels as a sort of research subject. We have no report to present, but a progress report has been made to the Committee, which indicates we may have something very interesting to report later.

The reports that we submit are submitted as information. There is no action that we request on the part of the convention, but if there is any question that comes up or any ideas that we can get from the convention on the subject of deep well pumps, we would be glad to have them.

Mr. C. E. Lindsay (New York Central & Hudson River):—I assume that the Committee will in time continue the investigation of proper design of water scoop on locomotives. Am I right?

Mr. Ferriday:—Yes. We were not able to finish our report on that. We hope to present some data with reference to relative costs of different installations.

We have presented plans and a description of a very extensive installation on the Lake Shore, but we expect to cover that more fully, and also to present a further report on the economics of the track pan, a partial report of which was made two or three years ago.

Mr. Lindsay:—Anyone who reads Mr. Vaughan's paper will be impressed, I think, with the fact that we may design a trough and all of its fixtures with the greatest care, but that the design of the scoop from the engine has a very great bearing on the efficiency of the device we install upon the track, and that one cannot be designed properly without a proper design of the other. In conducting the tests at Herkimer, we found that the scoop had a very bad choking effect and increased the waste and decreased the quantity taken into the tank, so that it is to be hoped that if it is possible to do so, the proper mechanical society may be asked to co-operate with this Association in making further tests with scoops of different kinds, on pans of different kinds.

Mr. W. McC. Bond (Baltimore & Ohio):—I would like to ask the Committee if they have succeeded in getting any information in regard to the water softening plants that have been put out of service? I am told that some of the roads throughout the country that have had water softening plants have put them out of service.

Mr. Ferriday:—We have not had any information of any water softening device being discontinued.

The President:—The Committee will be relieved, with the thanks of the Association.

DISCUSSION ON YARDS AND TERMINALS.

(For Report, see pp. 913-954.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON YARDS AND TERMINALS.

HADLEY BALDWIN,
G. D. BROOKE,
W. M. CAMP,
J. L. CAMPBELL,
MAURICE COBURN,
C. DOUGHERTY,
L. C. FRITCH,
GEORGE W. KITTREDGE,
C. E. LINDSAY,
C. F. LOWETH,
B. H. MANN,
HUNTER MCDONALD,
WILLIAM MCNAB,
S. S. ROBERTS,
C. H. SPENCER,
JOHN G. SULLIVAN,
W. I. TRENCH.

The President:—The report of the Committee on Yards and Terminals will be presented by Mr. C. H. Spencer, the Chairman.

Mr. C. H. Spencer (Washington Terminal Company):—On the first subject assigned the Committee, "to report on typical situation plans of passenger stations, of both through and stub types, with critical analysis of working capacity, and include a review of the different methods of estimating their capacity," the Committee has presented a report on six stations, as shown at the bottom of page 913. Following this is a description of the subjects handled in dealing with the methods used in estimating capacity. These are not offered for adoption, but merely for information.

The Committee presents three diagrams that will be found immediately following page 918. The first diagram is a modification of what is known as the Verdeyen diagram, used by the Belgian State Railways, and is fully described in the Bulletin of the International Railway Congress issued in September, 1908. As explained in the text, a study of this plan, together with the use of the diagram, will develop its use for the purpose intended. The Committee has added to the diagram, as shown in the Bulletin, certain symbols to represent the character of equipment used, and also at the righthand end of the diagram a table showing the platform capacity in cars, and have added also the train numbers and route numbers, which makes this diagram, in the opinion of the Committee, very complete.

The second and third diagrams in conjunction with a track plan of the Broad Street Station, which is shown at another place in the book, is a diagram which has been in use by the Pennsylvania Railroad, and was developed for the purpose of studying the capacity and possible electrification at the Broad Street Station of that company in Philadelphia. Diagram D, the last one, is a diagram devised by the Committee during the past year. The text is sufficient, if studied, to show the uses to which this diagram can be placed. I want to say that while this diagram appears to the eye as very intricate, in actual practice, if the recommendations of the Committee are followed, it is not at all so.

The Committee recommends in its report that for practical use, instead of taking an arbitrary time, say, of two hours, that the time be shortened so as to limit the number of movements to a sufficient number so that the diagram may be perfectly plain, perhaps 50 to 100 movements. This diagram covers something over 200 movements. We purposely used the busy conditions at the Broad Street Station to demonstrate the fact that the diagram could be successfully used under the most trying conditions.

The Committee does not present any of these diagrams for printing in the Manual, but simply as information.

On page 924 the Committee presents certain conclusions for adoption and printing in the Manual.

The President:—Unless there are objections to these conclusions as they are read, it will be understood that they are approved.

The Secretary:—"(1) A holding yard should be directly connected with platform tracks to provide for a quick emptying and refilling of the latter."

Mr. L. C. Fritch (Chicago Great Western):—I would like to know what the Committee means by "holding yard" in that connection.

Mr. B. H. Mann (Missouri Pacific):—A reservoir, you might say, for empty equipment in advance of placing the draft out at the station platform.

Mr. C. H. Spencer:—I would also say to Mr. Fritch had he been in Washington on the morning of the 4th of March he would have seen the necessity for just such a yard as this for quickly handling equipment from storage yard during a period of heavy traffic.

Mr. L. C. Fritch:—I believe "storage yard" is a preferable term.

Mr. Mann:—Storage yard does not correctly represent the meaning of the Committee. A storage yard may be a yard in which the empty equipment is placed for various purposes after the receipt of the train. The wording here is intended to cover the condition where, as the equipment comes from the storage yard, it comes close up to the throat of the station, so as to have the draft ready to be pushed into the station just as quickly as the track is empty. Storage yard has a broader meaning. Holding yard has a narrower meaning than the latter.

Mr. G. D. Brooke (Baltimore & Ohio):—Is there any definition in the Manual covering such a term? If not, I suggest that it be added.

The President:—There is no such definition, but the Committee will furnish a definition.

Mr. Mann:—Storage yard, as defined in the Manual, is "A yard in which cars are held awaiting disposition."

Mr. C. H. Spencer:—The Committee wish to amend conclusion No. 2, page 401 of the Manual, which at present reads, "At passenger terminals where large quantities of baggage and express must be handled and it does not appear expedient to provide intermediate platforms to be used exclusively for this service, it is recommended that (where conditions permit), baggage and express be received, delivered and

handled below the train floor, and raised and lowered by elevators, conveniently located, to avoid interference with the movement of passengers," the Committee desires to amend that section by inserting the words "or above" immediately after the word "below" in the fifth line and the words "(as grade conditions demands)" after the words "train floor." The conclusion will then read as shown on page 924 of the Bulletin.

Mr. William McNab (Grand Trunk):—It seems to me the recommendations would read better if we reversed the wording, "It is recommended that, wherever conditions demand, baggage and express be received, delivered and handled below or above the train floor (as grade conditions permit)," etc.

The President:—The Committee will accept that.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—There seems to be some question about the wording regarding the receiving of baggage and express. In most cases that must be done at grade and then the baggage and express are lowered or elevated to platforms. It is received and delivered at grade, and lowered or raised in order to deliver it to or take it from the trains.

Mr. C. H. Spencer:—I presume in the larger number of smaller stations that may be true. In a large number of our stations, however, baggage is received below the grade. For instance, in Washington, the baggage is received below the grade and elevated to the train floors by means of elevators. In the New York Pennsylvania station the baggage is received above and is lowered to train floor. It is to meet these varying conditions and to bring out the best arrangement possible for handling baggage with the least interference with the movement of passengers that the Committee made this conclusion.

Mr. Hunter McDonald:—I understand that the Committee in this recommendation is covering those cases where the railroad station is either above or below the street level.

Mr. C. H. Spencer:—I will state that in the plans adopted by the Association some two years ago we made that provision, provided for a difference in grade between the street and the station platform.

The President:—The Committee will proceed with the next conclusion.

Mr. C. H. Spencer:—"Conclusion (3) To provide for proper coupling of cars a maximum curvature for storage and loading tracks of six degrees is recommended."

Mr. J. L. Campbell (El Paso Southwestern):—It happens at the present time that we are taking out a 7°-30′ curve at our station at Douglas, Arizona, on account of difficulty of coupling passenger equipment on that curve. We are having trouble there.

Mr. C. H. Spencer:—I will say, after a great deal of correspondence and investigation of this subject, the conclusions reached were that with a six-degree curve as a maximum the best results were obtained. Above the six-degree there seemed to be considerable difficulty in coupling.

The Secretary:—"Conclusion (4) For safe, efficient and economical operation on station throat tracks the curvature through switches should not exceed that of a No. 8 slip on tangent."

Mr. C. E. Lindsay (New York Central & Hudson River):—I move the omission of the word "safe."

Mr. Maurice Coburn (Vandalia Railroad):—Is that not a roundabout way of stating the sort of curve? Could the Committee not tell us the degree of curve?

Mr. C. H. Spencer:—The Committee rather objects to the omission of the word "safe." I suppose the reason that objection is made is a question of policy. We had a great deal of discussion in the Committee meeting as to entering into questions of safety, but we have taken this position: the Eastern roads, and I think it is spreading out into the West, are putting the question of safety first. I think that is illustrated by the New Year's address sent out by President Willard to the employés of the Baltimore & Ohio Railroad. The time has come when this department has got to enter into questions of safety, and I believe it is the province of every Committee to enter into these questions and to recommend what appears to it to be the safe and efficient method. Derailments occur because of the use of long engines around too sharp curves, particularly where there are switches in those curves. We have recently had to take out some switches, not only because they were not efficient, but because they were not safe, and the Committee in making this recommendation believes it is taking the stand that should be taken by every member of this Association, and that is for the adoption of those things that are not only efficient and economical, but that are recognized by every member as being safe, and as will be recognized by the railroads, as a body, as being safe, and we do not feel that we should be at all backward in expressing our opinions on those matters. As to the reason that we use the expression, "No. 8 slip switch on a tangent," a great deal of the trouble experienced in curves is in switches, and it has been found by experience that the curvature through a No. 8 slip switch, although that varies on the different roads, is about the maximum of what should be used.

Mr. L. C. Fritch:—I think the word "safe" is unfortunate in that connection. By adopting that we practically say that anything greater than that, or say a No. 7 or No. 6 slip switch, is unsafe. We have many installations in this country that have a curvature which exceeds that of a No. 8, and to make the change would involve very large expenditures. The operation through them, if it is conducted properly, is just as safe as it is through a No. 8. I think it is a mistake for us to set a precedent of this kind. It gives opportunity to place upon railways burdens of making expensive changes, or which are impracticable. If the word "safe" is omitted from this clause it will read just as well and will be very much better, and avoid any complications that might arise by condemning anything sharper than a No. 8.

The President:—Your idea is that safety can be secured by proper control of the speed?

Mr. Lindsay:—A road that adopts a No. 8 turnout for its equipment may be entirely justified, whereas another road, with other equipment, may be entirely justified in using a frog as low as No. 6. We have just about completed the Grand Central Terminal, in which 6½ frogs are used. Are we to be condemned and compelled to rebuild on the ground that it is not safe? We think it is perfectly safe under the operating conditions and the equipment that we have. I think this conclusion would be entirely proper if the word "safe" is not used, and I think it would be entirely improper if the word "safe" is used.

Mr. Coburn:—Mr. Spencer misunderstood my point. The point was in the method of telling how sharp the curve shall be. I agree thoroughly with Mr. Lindsay and Mr. Fritch in this matter.

Mr. W. M. Camp (Railway and Engineering Review):—I believe that the word "safe" in this recommendation is both superfluous and unfortunate. A turnout which is unsafe is neither efficient nor economical. I also think that too much has been made of this cry of "safety first." Engineers habitually bear in mind that safety is the first consideration in designing yards or any other kind of railway layouts. This word "safe" could be inserted in practically every recommendation that this convention might make, but the safety habit of engineers is too well understood to require it in any case, or, at most, in but few cases. Should it be used in some recommendations and not in others, it might be inferred that the question of safety had perhaps been overlooked and, therefore, I would like to see it stricken out.

Mr. C. F. Loweth (Chicago, Milwaukee & St. Paul):—I am quite in accord with the motion to eliminate the word "safe." I think we ought to do it, and hope the motion will be carried.

Mr. John G. Sullivan (Canadian Pacific):—I am in accord with the speakers, for another reason. The word "safe," without giving any speed, means nothing whatever.

Mr. Mann:—In answer, the Committee analyzed each concrete case, then formulated a rule for all alinements of the throat that it considered would be thoroughly understood.

Mr. S. S. Roberts (Consulting Engineer):—I agree with the Committee in regard to the statement of the curvature. It is a warning against placing a No. 8 slip switch on a curve. Without qualification, the statement, "the curvature shall not be greater than the curvature of a No. 8 slip," may lead the thoughtless or inexperienced to place such a slip so that part of it will be on the inside of a curve, in which case the degree of the curve in the slip is increased. The Committee's statement conveys to me a clear idea of the definitely fixed maximum degree of curve it is desirable to use and indicates, if a single or double slip is so located, that one movement through it is from the inside of a curve, some number of slip with a smaller frog angle than the No. 8 must be used.

Mr. Brooke:—It seems to me that limiting the curvature to that of a No. 8 slip is somewhat unfortunate. In most of the terminals in large cities the property cost enters very highly into the matter of ultimate efficiency, and there are frequently limiting conditions, such that that curvature cannot be obtained. At the same time, we have a great many terminals being operated efficiently with curvature sharper than that defined.

Mr. C. H. Spencer:—I would like to say, in answer to Mr. Brooke, that we have had a great deal of correspondence with the different roads of this country in regard to this subject and we found that a very large number of them who have No. 8 switches on curves are cutting them out. In fact, I have in mind one company that spent a great deal of money this year taking out a lot of them and putting in No. 10s; they had No. 8 switches on three-degree curves, and they were forced to route Baltimore & Ohio class P-1 engines over special routes. We could not put them around the inside of these curves. They went on the ground every time, and it was necessary to take them out to overcome this difficulty. The Pennsylvania Railroad are doing the same thing, and other roads with whom we have had correspondence have found it necessary to limit the curvature to a No. 8 slip switch on tangents.

Mr. L. C. Fritch:—I believe we should legislate for the submerged tenth as well as those who are in a position to accommodate themselves to ideal conditions. There are conditions in this country where it would cost a lot of money to conform to this requirement, and we must be careful in making our rules to avoid conditions that are impracticable. We have in mind the misfortunes of the New York, New Haven & Hartford Railroad. I believe this can be modified so that it will read "where practicable, the curvature of through switches should not exceed that of a No. 8 slip on tangent." Any engineer would be condemned for using less than a No. 8 if it were possible to put in a No. 8, and I think we should consider the conditions that exist to-day that cannot be altered without heavy expense.

The President:—The Committee will accept the proposition to remove the word "safe" in that paragraph.

Mr. Loweth:—I want to ask the Chairman if all of the No. 8 switches are to be removed, or simply those on some of the divisions?

Mr. C. H. Spencer:—That is a question I cannot answer. The place in question was not on the Baltimore & Ohio Railroad, but on the Washington Terminal, over which the Baltimore & Ohio operates. The Pennsylvania are looking forward to eliminating all No. 8 slip switches, where they come on curves.

Mr. C. Dougherty (Cincinnati, New Orleans & Texas Pacific):—In connection with this it seems to me the proper design of connections with slip switches in terminal stations involves so many surrounding conditions, such as the class of engines used or equipment, the speed at which trains are expected to move over the switches and the cost of

providing rights-of-way sufficient to put in a lower number of frog, makes it impossible for this Association to adopt a general statement in regard to such matters.

Mr. Lindsay:—On our road we have had a great many derailments of a certain type of locomotive on No. 7 slips and turnouts. The No. 7 slip is in general use, but we had so many derailments of engines supposed to be designed for use around No. 7 slips, it got to be a question whether we would have to throw away the engines or rebuild the slips. We secured the cooperation of the Motive Power Department and tested out those engines, and we have shown where the error in design of the locomotive was and they have corrected it, and made it perfectly possible for that engine, a big one, to go around those slips without any danger of derailment. I believe firmly it is perfectly desirable to limit to No. 8 where it is possible to do so, but to say it must be done for safety is going too far.

Mr. J. L. Campbell:—There may be a question as to the interpretation of the words "efficient and economical." I suppose the Committee had in mind the things involved only in running the train around those curves. However, if all of the elements are taken into consideration the substitution of lighter curves in some cases cited might show that it will be neither efficient nor economical to do that. I think, finally, we would have to take into consideration the cost of making the changes, the capital which you would invest in securing lighter curves. There is a question in my mind whether it would always be true that the substitution of a curve not greater than for a No. 8 slip would be either efficient or economical. I think the suggestion offered by Mr. Fritch is a good one, and I wish to ask if the Committee will go a step further and modify that to read as follows: "Where practicable, on station throat tracks the curvature through switches should not exceed that of a No. 8 slip on tangents."

Mr. George W. Kittredge (New York Central & Hudson River):—If the Committee is not willing to accept that without a motion, I make a motion that the report be amended to read as the last speaker has suggested.

The President:—The Committee will accept that.

Mr. C. H. Spencer:—Mr. President, I move the adoption and insertion in the Manual of the four conclusions as modified.

(Motion seconded and carried.)

Mr. C. H. Spencer:—Please turn to page 937. The Committee offers two conclusions for adoption and printing in the Manual:

"(1) Where tracks are set aside for holding empty cars, the grade leading to such empty tracks should be increased so that empty cars will move with the same velocity as loaded cars switched to adjoining tracks.

"(2) The Committee has investigated the 'Cut List' system of handling cars on the hump and recommends it as being safe and efficient. This system is briefly described as follows:

"The yard clerk makes up a list of cars to be switched and tracks they are to be placed on in receiving yard, cut No. 1 being the first car to go over the hump.

"Cut list form accompanies this report. It is perforated on three vertical lines, so the list may be divided up into four parts, each part being a duplicate of the other.

"Where switches are thrown from a tower, one copy of the list is given to the towerman and one to the man cutting off cars on the hump. Where switches are thrown by hand, each switch tender has a copy of the cut list, as well as the man cutting off cars on the hump."

We wish to change conclusion No. 2 from the way that it reads now in the Bulletin, to read as follows: "The cut list system of handling cars on the hump is recommended as being safe and efficient and is briefly described as follows: The yard clerk makes up a list of cars to be switched and tracks they are to be placed on in receiving yard, cut No. 1 being the first car to go over the hump. Cut list form accompanies this report. It is perforated on three vertical lines, so that list may be divided into four parts, each part being a duplicate of the other. Where switches are thrown from a tower, one copy of the list is given to the towerman and one to the man cutting off cars on the hump. Where switches are thrown by hand, each switch tender has a copy of the cut list, as well as the man cutting off cars on the hump." This conclusion to be followed by a diagram of the cut list on the opposite page.

Mr. Kittredge:—I would like to ask if it is necessary to put the word "safe" in that second conclusion? It carries with it the insinuation that any other process is unsafe.

Mr. C. H. Spencer:—Not necessarily so. The Committee visited a number of hump yards this year. We saw several methods of marking the cars going over the hump. We did not mention the ones that we felt were decidedly unsafe. We saw men running in front of cars, chalking on the ends of cars. We did not express our opinion in the Bulletin as to that. We saw men running along the side of the cars, taking hold of the grab iron, reaching around the ends and putting figures on the cars. This cut list system is in use on the Pennsylvania Railroad, in their large yards. In the work of marking up the cars as done on this list there is no occasion for a man to get injured in any way in giving information to the towerman or to the switchman as to where those cars should go. I do not feel that there should be any objection to the word "safe" there. It is manifestly safe—perhaps it is axiomatic, but we do wish to call this list emphatically to the attention of this Association, not for the purpose of criticising any other method that may be in use, but as being not only efficient but a safe method of handling cars.

Mr. L. C. Fritch:—It seems to me this is a question of operation of the hump yard and not really an engineering question. I cannot see the necessity of our adopting a recommendation of this kind. It

has nothing to do with the designing of the yard or any engineering features. If it is intended to put this matter in the Manual, it would be my opinion that it ought not to be adopted.

Mr. C. H. Spencer:—May I quote for Mr. Fritch the object of this Association as printed at the top of the first inside cover of the Manual? "The object of this Association is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways." (Applause.)

Mr. Mann:—I would like to call your attention also to the subjects that were assigned to the Committee by the Board of Direction. The third subject reads: "Report on developments in the design and operation of hump yards."

Mr. S. S. Roberts:—The use or lack of use of this switch list will have some effect on the design of the yard. The method of marking on the ends of the cars the number of the classification tracks to which the cars go necessitates a very much more complete and much more carefully designed lighting system on the hump than where the cut list is used, because it is necessary that the switchmen, where the ladder switches are operated by hand, and the towerman, where power is used, see the numbers on the ends of the cars by night as well as during the day. Difficulties have been experienced in some yards and some roads have spent a good deal of money because they did not use the switch list.

I think the word "safe" in connection with this switch list is entirely proper. I have visited a number of yards, operated in different ways, where switch lists were not used and have seen men dancing around in front of moving cars, chalking numbers on the ends of these cars, and have wondered how they escaped injury. I would not consider such a job for five minutes, no matter what it paid. I think the consideration of safety is entirely proper in this Association.

Referring again to the illumination required on humps where the switch list is not used. If the intensity of the light is sufficient to enable the switchmen or towerman to see the numbers marked on the ends of the cars, the car riders for a time after passing the hump are almost blinded and travel a considerable distance down the yard before their eyes become accustomed to the darkness. There is more probability of damage on account of cars coming together and of delay on account of cars stopped short that must be later shoved to coupling.

Mr. Mann:—It was the thought of the Committee, as well, that the cut list is a great help in O. S. & D. work. A man in switch cabin by means of the cut list keeps a record of each rider. If there is any damage to a car or the freight in a car, it can be directly traceable to one individual, the rider, provided we file away the cut list.

Mr. Brooke:—I would inquire from the Committee if they consider that these methods, which they state were unsafe, were efficient? It seems to me that the word "efficient" covers the matter of safety well enough; but a method of operation which is inherently unsafe is at the

same time inefficient, and I will be very glad to see the word "safe" omitted.

The President:—The Committee will accept that amendment, and it is understood that the word "efficient" takes the place of "safe." Recommendations Nos. 1 and 2 are now before the convention. The Chair thinks it would be well to read it so that there shall be no mistake—that is, recommendation No. 2.

Mr. C. H. Spencer:—Recommendation No. 2 now reads: "The Committee has investigated the 'cut list' system of handling cars on the hump and recommends it as being efficient, and the system is briefly described as follows:

"The yard clerk makes up a list of cars to be switched and tracks they are to be placed on in receiving yard, cut No. 1 being the first car to go over the hump.

"Cut list form accompanies this report. It is perforated on vertical lines, so that it may be divided into multiple parts, each part being a duplicate of the other.

"Where switches are thrown from a tower, one copy of the list is given to the towerman and one to the man cutting off cars on the hump. Where switches are thrown by hand, each switch tender has a copy of the cut list, as well as the man cutting off the cars on the hump."

The President:—Unless there is objection, these two recommendations are approved.

Mr. W. I. Trench (Baltimore & Ohio):—I believe in addition to giving this information to the four persons listed here, that the car rider should also have the information, and this can only be given efficiently by chalking on the ends of the first car or cut. If the car rider does not know on which track his car is going he has not means of determining just what amount of breaking should be done, and if the track into which he is going is nearly full he will not set his brakes hard enough, and will cause a collision. If he goes into an empty track and he is required to let his cut go to the end of it, he may set his brakes too hard and not go far enough. I believe, in conjunction with the method described of informing every one concerned as to where the cut is going, the car rider should have that information also.

Mr. Mann:—Each track is presumably marked by a light on the first car, so that the Committee feels the rider has the information necessary.

Mr. Trench:—I did not refer to giving the information on a sheet of paper. The method which I have seen used successfully is to mark, for instance, on the first car of the cut, "five cars, track 18," or some such notation as that. It is not possible for the man who is cutting off the cut to give the car rider this information, because he is on the opposite end of the cut. If it is necessary, to avoid a collision, to apply the

brakes at the near end of the track into which he is entering, he should have this information.

Mr. C. H. Spencer:—There is no end to the extent to which this cut list might be carried. It is a matter of how the different roads may want to operate it. There is no objection to giving the car rider one of these lists or anyone else who might have use for it. We have provided in our recommendation, as last presented, a multiple cut list which would furnish sufficient copies to extend the system as far as it is desired.

Mr. S. S. Roberts:—In watching operation where the cut list is used, it seems entirely unnecessary to mark on any car where the cut is going. The foreman tells the rider where the cars are going. He says, for instance, "Take five cars to track No. 4." That is all the information the rider needs. He should have memory enough to retain this while he rides down the hump. It is his duty to know what tracks are "fast" and "slow," and whether or not he has a long or short ride.

Mr. C. H. Spencer:—I move the adoption of the two conclusions as revised.

The President:—Those in favor of adopting the two conclusions in the modified form, as recommended practice, and for publication in the Manual, will so indicate.

(Motion carried.)

Mr. C. H. Spencer:—The last subject assigned to the Committee is entitled "Development in the mechanical handling of freight by mechanical means." We present a further report on this subject for information only. The Committee has done much work along these lines during the past two years, and I want to say on behalf of Mr. Clift, who was the chairman of the sub-committee in charge of this work, that he received the hearty cooperation of all the railroads to whom we have made application for assistance, and Mr. Clift has taken a vital interest in this subject. I believe the members who read the report will find a great deal of information of value in this report, and they can get the best there is out of it.

The President:—The Committee has presented, I think the convention will agree, a very complete and enlightened report that will be useful in all branches of railroad work, relating to the operation of yards and passenger stations.

Mr. L. C. Fritch:—Before the Committee is relieved, I would like to make some suggestions as to its future work. I handed one of the reports of this Committeee to a very prominent designer of large terminal stations and he said it was the first report that he had seen that had treated in a scientific way the question of the design of large passenger terminals. He, of course, has made a study of the subject. This gentleman said that there was an alarming ignorance on the part of engineers in this country upon the needs of terminal facilities, especially passenger terminal facilities.

It seems to me that the Committee can do very important work along the line of establishing units of capacity. Take, for example, the track capacity; the Committee could determine what is the relative unit capacity for the busiest hour of a terminal with stub tracks as against one with through tracks. Then the Committee could also consider the relation of the platform space to track capacity. Then, again, the question of area of passenger station waiting room and other service facilities.

I think this is one of the most vital questions which confronts us to-day. We are being called upon to expend millions of dollars upon large union passenger stations and we should have some guide as to what shall be the capacity of these stations. It not only touches on the large terminals, but the smaller terminals. We are being pressed for an increase in the capacity of our passenger terminals even in the case of our smaller stations. If we can adopt some rule showing what the unit capacity of terminals shall be we can defend ourselves and say that the existing station is large enough for present needs, and in that way often postpone heavy expenditures.

I believe along these lines the Committee can do valuable work. It has made a most excellent beginning and has given us data of inestimable value.

The President:—The Committee is relieved with the thanks of the convention for its interesting report.

DISCUSSION ON GRADING OF LUMBER.

(For Report, see pp. 955, 956.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON GRADING OF LUMBER.

DR. HERMANN VON SCHRENK.

The President:—The report on Grading of Lumber will be presented by the Chairman, Dr. Hermann von Schrenk.

Dr. Hermann von Schrenk (Consulting Timber Engineer):—Mr. Chairman, and Gentlemen, the report of this Committee is very short. We have to report, first, the adoption of the rules submitted to this Association last year and authorized for publication in the Manual, by three of the large lumber-producing associations of the country. The yellow pine rules were adopted by the Yellow Pine Manufacturers' Association: the hardwoods by the Hardwood Manufacturers' Association of the United States, and the Douglas Fir, by the West Coast Lumber Manufacturers' Association. The Northern Pine Manufacturers' Association refused to accept the White Pine rules, and they will not be adopted as far as the White Pine Manufacturers are concerned. Your Committee, during the year, has gone over the various types of lumber, but most of the rules, owing to the fact that they were in poor shape when submitted, were not in condition for submission this year. Referring to the rules submitted, in Bulletin 144, last year, regarding cypress, these have been standing a year, and after going over them again this year your Committee begs to recommend their adoption for inclusion in the Manual, and I would make a motion to that effect.

(Motion seconded and carried.)

The President:—This is all the Committee has to offer for action. If there are no further remarks, the Committee will be relieved, with the thanks of the Association.

DISCUSSION ON ROADWAY.

(For Report, see pp. 957-986.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ROADWAY.

W. M. DAWLEY.

The President:—The report of the Committee on Roadway will be presented by the Chairman, Mr. W. M. Dawley.

Mr. W. M. Dawley (Erie Railroad):—The Committee on Roadway had under consideration the past year four subjects, which are given in the report.

Considerable information has been collected and will be presented later in the Bulletin.

The Committee has been unable to obtain any further information than that published in the Proceedings for the year 1912, Vol. 13, pp. 95 and 96. The Chairman of the Ballast Committee has recommended to the Association a series of tests to be made, to determine the deformation of the roadbed. The tests, when made, should contain some provision for determining the amount of pressure exerted on the roadbed and the stresses developed in the rails and ties due to inequalities in the bearing power of the roadbed. Any tests which are made should cover the entire structure—rail, ties, ballast and subgrade or roadbed. We have requested the Board of Direction to set aside an appropriation, but we have not succeeded in getting their consent as yet. We have some hope that, with the approval of the Board of Direction, we can have some assistance from the outside which will enable us to carry on some experiments along this line. The third subject, "Report on Tunnel Construction and Ventilation;" we submit some notes on ventilation of subways, the New York City subways and the Hudson River tunnel, for information. On the fourth subject, "Economics of Roadway Labor," the Committee has done some work, but it is not prepared to present the report at present. For the year 1914 the Committee would recommend that the subjects (2), (3) and (5) be reassigned.

The President:—Are there any questions, comments or suggestions for this Committee in connection with their next year's work? If not, this report will be received as information and the Committee relieved, with the thanks of the Association, for the valuable information presented.

DISCUSSION ON RAIL.

(For Report, see pp. 169-578.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RAIL.

W. C. Cushing.	M. H. Wickhorst.	John G. Sullivan.
C. E. Lindsay.	W. L. Seddon.	S. N. Williams.

The President:—We will now have the report of the Committee on Rail, which will be presented by the Chairman of the Committee, Mr. W. C. Cushing.

Mr. W. C. Cushing (Pennsylvania Lines):—You have seen our good friend Rudd depart from the rostrum in a jovial frame of mind. He seems to think that he has solved the signal question for all time to come, but undue pride leadeth to a fall. We of the Rail Committee, on the contrary, do not believe that the Rail question will ever be settled. In proof of this we take you back 49 years.

Apropos of the question of steel rails it is interesting to read the following remarks made by former President John Edgar Thomson in his annual report to the stockholders in 1864, nearly 50 years ago:

"The rapid destruction of iron under the high speeds and heavy locomotives now used upon railways has become a subject of serious consideration, not only to the managers of these improvements in this country, but also in Europe. When the Pennsylvania Railroad was planned, a locomotive weighing 45,000 to 50,000 lbs. was considered as the extreme limit to these machines, justified by prudence. But the demands of the public for high speeds has compelled the introduction upon all thoroughfares of more powerful engines. These could only be obtained by adding to their dimensions and weight, which has produced its natural result—great wear and tear of iron rails and the superstructure of the road. This evil has been still further increased by the inferiority of the rails now manufactured, compared with those placed upon railways when the edge rail was first introduced. It was then deemed essential that rails should be made from the best refined iron produced from selected ores. The great increase in the demand for iron under the rapid development of the railway system in England and this country soon caused the substitution of an inferior article, which seemed for a time to answer the purpose, but which experience has proven to be insufficient to resist the causes referred to, as continually operating for its destruction. A return to the quality of iron originally used on railways would be the natural remedy for this difficulty, but this will require time, as none of the rail mills have the required furnaces to refine their metal. In Europe this subject has been longer considered, and the determination appears to be general, to gradually substitute a still more expensive material—either a rail made wholly of steel, with a steel head only—or the wearing surface converted into steel after the iron rail is made. The present high cost of rails made entirely of steel will probably prevent their general adoption, although the rapid destruction at the termini and stations, where the iron rail in some positions does not last six months, will fully justify their introduction. For the purpose of testing the relative value of steel and iron rails in such positions, we have procured 150 tons of rails made wholly of cast steel. A trial is also being made of a

rail with a steeled wearing surface passed through the rolls, when drawn from the converting furnace, which promises well. It is understood that favorable results have been obtained from rails, the top plate in the pile from which they were made being puddled steel. If the two metals can be firmly welded together, this improvement in railway bars will be generally adopted. This is a subject of such great importance to the Company that it will continue to meet the earnest attention of your Directors, and if necessary to effect the reformation desired in the quality of rails it should become important to erect works to effect that object, such a policy will be adopted. The frequent renewal of rails is not only expensive, but it adds to the interruption of the traffic of the line."

The particular work of the Rail Committee of last year was to have been the recommended change in the design of rail sections if found to be desirable. A great deal of study has been given to the subject, but the Committee is not yet ready to report a favorable conclusion of its studies. Consequently its work for the next year will be a continuation of that study. It has also continued to furnish your Association with new information as it has obtained it, some of it based upon a great deal of individual research work from time to time, for the improvement of our knowledge of the whole subject.

The only conclusions we have to offer to the Association for adoption this year are in line with proposed revisions of what is already in the Manual. These conclusions are on page 180.

As these changes are due to criticisms made at the last annual convention and those received during the year, it is presumed that they are in line with the wishes of the Association, and I make the motion now for their adoption. The specifications are printed in the Manual and these proposed alterations are only some slight changes to improve them. I move the adoption of conclusion No. 1.

(Motion carried.)

Mr. Cushing:—Inasmuch as our work is being practically done under the direction of the American Railway Association, these specifications have already been submitted to that association, and been adopted by that association as tentative specifications, just as we have adopted them, and as we make changes in the future we will ask that association to approve of the changes also. The specifications can never be considered finished, and that is why the rail question can never be considered as a finished one.

Nos. (2), (3), (4) and (5) are changes in the adopted forms made necessary by changes in the specifications.

Mr. C. E. Lindsay (New York Central & Hudson River):—I have no criticism to make of the report, but we have recently sent some of our young men out to the mills to watch the process of manufacturing the rails, and they all came back impressed with the idea that while our rules for maintenance require the new rail to be handled carefully in unloading, they find in the mill that the rails are slid off skids and dropped into gondola cars, a distance of six or eight feet. I ask if the Committee has covered that feature of the loading of the rails at the mill?

Mr. Cushing:—It seems to me that all the instructions necessary on that point are given. I am not one who believes in the tender handling of rails. I think if they get a little rough handling it may develop some of the trouble we do not find otherwise. A rail is ostensibly for the purpose of being rough handled in the track, and I believe we have taken care of the matter you bring up as fully as necessary.

(Conclusions 2, 3, 4 and 5 were each adopted by separate motion made by Mr. Cushing.)

Mr. Cushing:—I might say that the Rail Committee will be glad to have any suggestions from any of the members, as this work can best be handled by taking suggestions under advisement in committee deliberations.

Mr. W. L. Seddon (Seaboard Air Line):—I would like to ask the same old question again, and that is whether we are making any progress in procuring from the manufacturers the acceptance of our specifications without extra charge. I understand there was a conference held last year, but I have never heard the result of it.

Mr. Cushing:—The Committee feels that distinct progress in the quality of rails has been made and we feel that the constant study and agitation of the subject has led to additional improved results. There are many details which we have criticised which have appeared almost impossible of solution to the rail manufacturers, with the present knowledge of the art. They, as well as ourselves, are making a determined study of the subject, and are endeavoring to bring about improvements. With this continued work on the part of the rail manufacturers and the railway engineers, we feel that ultimately we ought to find that we have gained very materially in our object.

If you will look back to the beginning of this work, when the Association was established, and examine the old specifications as compared with the new, I think you will find that a great many new points have been gained and placed in the specifications which are of distinctive advantage. We have got to keep the work up; we have not solved the entire question yet. Someone is always making original investigations for the improvement of the art and we hope to profit by all these studies. You have had some examples of that in the Bulletins that have been published in the last year, for they have given some very valuable information.

Mr. Seddon:—My question is this, I have taken the specifications which we adopted and submitted them to the manufacturers and they want an extra amount for rolling rails according to these specifications. I want to know if anyone in the Association has been able to get rails rolled according to our specifications without paying an extra price.

Mr. Cushing:—When the question of price comes in, that is not possible of solution by this Association. A joint committee of railway presidents and presidents of the steel manufacturers undertook last year to take up that phase of the question and held about three meetings. We suppose that those meetings will be continued, with the object in view

of settling not only the quality of the material, but also the price. At present, every time new restrictions in specifications are offered, an elevation in price is asked for by the manufacturers. Then, as to what can be accomplished when that question arises, is a matter which has to be fought out by each company itself.

Prof. S. N. Williams (Cornell College):—If it is in order, I would like to express the very high appreciation I am sure all the members of this organization feel for the extremely valuable report that has been presented to us. Personally, I feel that it could not be excelled by any scientific body in the civilized world, and I am sure the Committee deserves very great credit for the honor they have done our organization by the preparation of this full and exhaustive report.

Mr. John G. Sullivan (Canadian Pacific):—In rising to second that motion, I would like to thank the Chairman for the suggestion where to send letters about freak rails and such things. But another point that has bothered some of our inspectors is the definition as to defects, whether that would cover segregation of pipes, etc.?

Mr. Cushing:—That is a subject for a difference of opinion as yet. The Pennsylvania Railroad System has a definition of interior defect in its specifications to meet that very objection. The American Railway Engineering Association has refused, up to the present time, to put it in. It may come later, but they are not prepared to put in a definition of that sort yet, because they feel there is considerably more to be learned in regard to it. As far as I know the only road that has it in its specifications is the Pennsylvania, and it was introduced by that Company to try and avoid having disputes with the manufacturer.

Mr. Sullivan:—We have it in our specifications.

The President:—If the Association desires to hear a few words from our Engineer of Tests, Mr. Wickhorst, on the causes of failures so far as he has noted them, he will address you for a few moments.

Mr. M. H. Wickhorst (Engineer of Tests—Rail Committee):—Taking the statistics of rail failures as published in one of our recent Bulletins, 90 per cent. of the failures can be divided into two general classes. First of all, we have failures such as crushed heads, split heads and also in that should probably be included most of the web failures. This class of failures is traceable finally to the interior condition of the ingot from which the rails were made; that is, they are a matter of excessive segregation, which produces a brittleness in the interior of the section. Under wheel loads the head spreads sideways. The top metal is always ductile, but the interior metal may not be so, sometimes due to structural flaws, or laminations, but mostly due to excessive segregation of carbon and phosphorus, which makes extremely brittle, non-ductile material inside, so that when the top of the head spreads sideways, a crack develops internally, and finally comes to the surface at the underside of the head at its junction with the web. Sometimes, in the case of a badly-segregated rail, it will run farther into the web and come out to the surface at the side of the web. So a good many failures, classed as

web failures, would come under this head. That would include probably 50 per cent. of the failures. Then, in the second class, we have broken bases and broken rails, which I will simply state very briefly, we think we can now definitely trace to a seam in the bottom of the base. If the bottom of the base contains a seam, when excessive load comes on, or if there is an eccentric bearing, then the seam opens, and if the seam happens to be away from the center, a piece of the flange may break out, and we get a moon-shaped or crescent break. If, however, as is more generally the case, the seam opens up near the center of the base, the base will open up and a piece of the flange start to break off, and then the break goes through the whole of the section. So what are classed as broken rails (square breaks—angular breaks), and base breaks in general, can be traced to the presence of a longitudinal seam in the bottom of the base. This will probably include about 40 per cent. of the rail failures. These two classes will account for about 90 per cent. of all the rail failures of the country. Now, to sum up, we may say 50 per cent. (numerically) of the rail problem consists in getting sound metal of fairly even composition, and 40 per cent. consists in so rolling the steel as to avoid seams in the base. (Applause.)

The President:—Have any of the manufacturers any remarks to make in answer to the statements by Mr. Wickhorst, or the Committee? If not, we will consider the motion for a vote of thanks to the Committee carried.

DISCUSSION ON ECONOMICS OF RAILWAY LOCATION.

(For Report, see pp. 579-651.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ECONOMICS OF RAILWAY LOCATION.

J. R. W. Ambrose.	L. A. Downs.	W. G. Raymond.
W. G. Atwood.	L. C. Fritch.	S. S. Roberts.
F. J. Bachelder.	Edward Gray, Jr.	L. S. Rose.
W. McC. Bond.	A. J. Himes.	A. K. Shurtleff.
G. D. Brooke.	C. P. Howard.	F. S. Stevens.
A. W. Buel.	J. B. Jenkins.	John G. Sullivan.
M. L. Byers.	C. E. Lindsay.	E. E. R. Tratman.
W. M. Camp.	C. F. Loweth.	W. J. Wilgus.
J. L. Campbell.	Hunter McDonald.	

The President:—The report of the Committee on Economics of Railway Location will be presented by the Chairman, Mr. A. K. Shurtleff.

Mr. A. K. Shurtleff (Chicago, Rock Island & Pacific):—The Committee on Economics of Railway Location made a report at the 1910 convention, embodying certain conclusions with reference to Power and Resistance.

Since that report, your Chairman has received numerous letters from various sources criticising the report and calling attention to the fact that the resistance formula does not agree with the conclusions reached in other tests. In practically all of the criticisms it has been evident that the critic has not absorbed the substance of conclusions 5, 6 and 8 which cover the fact that condition of maintenance of both roadway and equipment and design of equipment materially affect the question of train resistance. It would seem that a number of the critics had not properly digested the body of the report.

There seems to prevail in many quarters an idea that the problems of this Committee can be reduced to an exact science and that simple formulæ can be deduced which will be mathematically correct in all cases when applied to the problems, regardless of the varying conditions.

This is impossible, owing to the fact that, were it possible to determine accurately the proper coefficients for each of the variables under different conditions, the formula would become very complex, and the judgment of the Engineer would have to be exercised in selecting the particular value of each coefficient for the condition which he thinks may exist. Such complicated equations would probably lead to no greater accuracy than the approximate simpler formulæ such as this Committee is attempting to establish.

We are trying to formulate *methods* for analyzing the problems of economics with reasonable accuracy. In so doing we give equations

which to our best knowledge cover average conditions. We expect that many roads will find the values of certain terms of the equations different under their conditions of operation from those given by this Committee. In such cases we believe that by the use of the methods to be proposed by this Committee and the coefficient values as they find them, satisfactory results will be obtained in weighing the relative economic values of various locations.

We hope to produce as early as practicable with available information, simple formulæ for the use of the man in the field, as a rough guide in his work, as well as formulæ with the necessary refinements for more detailed and accurate office estimates of relative values.

In our present report we have attempted to give a method for analysis of maintenance of way accounts, hoping at a later date to simplify to an equation form of sufficient accuracy for the field engineer.

We are attempting to analyze the items which are affected by volume of traffic on the basis of equivalent ton mileage, reducing locomotive and passenger train tonnage to an approximate equivalent of freight car tonnage using multipliers for each which in our present judgment appear to represent the relative damaging effects of a ton of each class as compared to the average effect of one ton of freight car and load.

In this connection I desire to call attention to the criticism of Mr. W. J. Wilgus, printed in the March Bulletin, and his suggestion that actual tonnage be used in dividing between the two classes. The points raised by Mr. Wilgus showing expenses created by freight service which do not apply to passenger traffic are excellent. At the same time the points brought out about the locomotives can be used as an excellent argument in favor of considering one ton of locomotive as producing greater damage than a ton of car and contents.

There are wide differences in opinion with reference to the relative damage per ton of passenger train when compared to a ton of freight.

It is certain that our roads require a much higher grade of maintenance both in labor and material to take care of the higher speeds of passenger service than they would if the entire tonnage over the rails was freight.

Unfortunately, the tests at St. Louis covering counterbalancing were only made on Atlantic passenger locomotives of the so-called balanced compound type, no such tests being made on simple locomotives.

With the exception of the Cole engine the nosing of these locomotives increased materially with the velocity, and in the Baldwin balanced compound was as great as 0.74 inches per revolution at 240 revolutions or 56 miles per hour. In this locomotive at the same speed the load on each wheel of the first set of drivers became very light through one-quarter of each revolution and returned abruptly in about one-eighth revolution. At 320 revolutions one forward driver left the rails. It is well-known that counterbalancing can be most satisfactorily accomplished in four cylinder locomotives, but statistics show that less than seven

per cent. of the Atlantic and Pacific type of locomotives are four cylinder types, the balance being simple.

The great bulk of passenger locomotives are of the simple engine type and at the high velocities undoubtedly cause much greater disturbance to the track than the balanced compound cited above.

In view of these disturbing forces at high speeds and the necessity of higher grade of maintenance, it would seem that the costs of maintenance in those accounts affected by volume of traffic would be greater per ton for passenger service than for freight and that the equivalent ton mileage principle should be used in the analysis of costs for these accounts.

The factors for reducing to equivalent ton mileage may vary somewhat. Data covering several years' operation on a four track road having two tracks devoted to each class of traffic would help materially in fixing the relative values. Unfortunately, this Committee has no such data and the present factors are used, trusting that in the future more complete information can be obtained and the factors adjusted to more nearly agree with the facts if such adjustment is found necessary.

Your Committee is indebted to Mr. R. N. Begien, its Vice-Chairman, for the excellent paper summarizing the results obtained by the extensive dynamometer tests on the Baltimore & Ohio Railroad, given in Appendix "B" of this report. A few slight changes are made in the conclusions as given in the Manual of 1911, due to results as Mr. Begien found them.

The principal change is in conclusions with reference to compensation for curvature. The changes recommended are logical, and give compensation for different conditions.

We believe the adoption of these changes advisable and that they will give greater satisfaction in practice.

I regret to say that Mr. Begien, the Vice-Chairman of the Committee, is unable to be here owing to his being detained on a case in court. The first thing that I would like to bring up is the proposed changes of the present Manual. Conclusion No. 2, page 436, of the Manual, reads as follows:

"Resistance of freight trains shows practically no change of resistance between seven and thirty-five miles per hour."

The proposed reading is: "Numerous tests demonstrate that there is no absolute value for train resistance. For practical purposes freight train resistance can be considered constant between velocities of 7 and 35 miles per hour." The object in making that change is that those who are not as familiar with the subject of train resistance as others, will know that it is utterly impossible to place an absolute value for train resistance, and we desire to so state in the conclusion.

Prof. S. N. Williams (Cornell College):—Mr. President, I move that the recommendation be adopted.

The President:—We would be glad to have discussion on this point. Discussion will bring out probably by questions or by remarks made some of the points which this Committee wish to impress on the members of this Association. My idea has been, and I think the members

of the Committee concur with the Chair, that they have now reached a step and published data that gives all the members of this Association a means of comparing their ideas with those of the Committee and will enable the members to bring information to this Committee for future work and future investigation. Heretofore we have been asked certain questions by the Committee, and the Committee were at one time rather discouraged because the questions asked by them were not fully answered; but now from this report we learn the object, and that enables every member of this Association to answer such parts of the questions as they are able to give accurately. The Chair believes that the result of this report will be a collection, during the coming year, of a large amount of information which will help this Committee in further investigation. We will be glad, therefore, to hear from any member of the Association before this question is put. The members will note that there is no change in the conclusion, excepting matter explanatory. Mr. L. C. Fritch, have you something to say on this subject?

Mr. L. C. Fritch (Chicago Great Western):—I have not much to say, except to repeat than any d—n fool can criticise, but it takes a wise man to suggest improvements. I do not know that anything can be offered that would be better than the Committee has given us. This subject is something that is so much involved that it is very hard to fix any formula or rules that will fit all conditions. In my own judgment I believe, however, that the limits between which there is a constant train resistance, in freight trains, at velocities between 7 and 35 miles per hour are rather high, if all the resistances are taken into account. I believe some resistances will increase with the speed and others will decrease with the speed, but it looks to me like the limits between 7 and 35 miles per hour are rather high. My own opinion on that subject is that the limits ought to be from 5 miles to 20 miles per hour. The lower limits are really the more practicable for freight train speed, and I think Mr. Begien, in his very valuable paper, reaches the conclusion that one is almost forced to reach, that it is almost impossible to establish any formula that will fix the train resistance; that with all the numerous tests that were made, according to his report, it is very hard to get anything that will serve as a guide. Of course, the main difficulty is that there is such a vast difference in equipment, and it is not always possible to fix any definite resistances. My opinion is that the railroads of this country are going to extremes in tonnage. They are overloading trains. I have always believed that there is an economical maximum tonnage which is very much below the maximum tonnage which locomotives are able to draw. I think that many roads are overloading their locomotives and expending more money in overtime and interference with traffic than would be the case if they established an economic loading, which would be lower than the maximum tractive power of the locomotive, the tonnage could be handled in such cases with less delay and interference. I think, however, from the information given by the

Committee that many of us can revise the tonnage ratings which we now have in effect and be very much benefited by it.

Mr. F. J. Bachelder (Baltimore & Ohio):—I ask if any actual tests have been made on the effect of superelevation on the tonnage rating? Some excessive elevations have the effect of stalling the trains.

Mr. Shurtleff:—Unfortunately Mr. Begien is not here. He took those questions into consideration in establishing his formula for compensation of curvature. However, there are some variables there. As the elevation varies the resistance for the low speed trains will vary on the curves, and that question would enter into our conclusion 4 with reference to the compensation for curvature. I think Mr. Begien, if he were here, could answer that, but I cannot, as I have not had time to familiarize myself with the extensive tests made by the Baltimore & Ohio. In fact, I am not as familiar with Mr. Begien's paper as I should be—I have not had the time to properly study it.

Mr. M. L. Byers (Delaware & Hudson):—Some time ago on the Baltimore & Ohio there were records kept of individual trains, which showed the tonnage of the trains, the number of cars, the type of engine; the cost data showing the coal consumption, also the wages to enginemen and trainmen, and other items, but I think those were the principal items included in the statement. This data was kept over a number of divisions, and the object of the reports was to try to arrive at the train loading from the basis of cost; that is, to find out what loading actually gave the lowest cost per ton mile in those particular items. Our experience at that time was that our trains were rather underloaded. Judging from those experiments, I rather think that, perhaps, quite a heavy train load can be shown to be economical.

Mr. L. A. Downs (Illinois Central):—I do not think it is the province of this Association to figure the cost of handling tonnage. If we figure out the train resistance and the best method of economical location of track to fit the conditions, etc., that is our work, and we should leave it to another department of the railroad to figure out whether that would be economical from a transportation standpoint. Take, for instance, as to whether or not the percentage of overtime made would equal the additional tonnage, I think we are getting into another field when we talk about the overtime made or the loss of time to the locomotive; that is, it is for this Association to figure out the train resistance and give the information to another department of our railroads and let them figure out whether or not it is economical to add ten per cent. to the tonnage which they can handle. I believe that the Committee has done well and has given us a formula which we have never had before and they are to be congratulated on it, but whether or not a locomotive should haul every pound it can, whether it is economical to have it do so, is another question, for another department of the railroad to decide.

Mr. G. D. Brooke (Baltimore & Ohio):—The question of the effect of superelevation is treated at the bottom of page 622 and top of page

623, in which attention is called to the fact: "Two engines (one helping) hauling 3,500 tons of coal ordinarily stalled on an 8 degrees 30 minutes curve with 185 degrees central angle with 5½-in. elevation. The elevation was reduced to 3 inches and no difficulty was had."

Mr. F. S. Stevens (Philadelphia & Reading):—I might say on the question of tonnage it appears to me to be a self-evident fact that the most economical tonnage to handle is that which will enable an engine to deliver the greatest tonnage from one point to another within a given time at the least expense. This holds true, no matter whether you wear your engine out in one month, or one year, or ten years—the quicker you wear it out, the better. The whole question is to move the tonnage, the most of it, in the least time, at the least expense; that is the whole thing to be worked out.

Mr. C. P. Howard (Consulting Engineer):—Referring to what the Engineer has to do in problems of grade reduction, in the first place we have to figure out what it costs to reduce a certain grade or cut out so many miles, and in the second place we have to figure how much it will save. I think the Engineer is required to submit an estimate of the number of train miles saved or economies of operation resulting in other ways.

The data that has been given by the Committee in connection with the Bulletin by Mr. Shurtleff on Fuel Consumption and Speed Diagrams gives information by which the fuel consumption, the time of the train, the loading, and the speed can all be calculated.

I have recently used this data in calculating the time and fuel consumption and other items for a division of 130 miles long, and the result was with a given engine, in a case where it would be practicable to haul a five-thousand-ton train at about 3.5 miles an hour over the proposed three-tenths per cent. grade, a four-thousand-train would probably be just about the economical limit. The fuel consumption per ton mile remains practically the same for the five-thousand-ton train as for the four-thousand-ton train. The time increases a great deal. In fact, the time for the four-thousand-ton train was about 15 per cent. greater than the time for a 2700-ton-train. The fuel consumption for the 2700-ton-train as calculated from the information given by Mr. Shurtleff in his Bulletin, checked out very closely with that given by the Superintendent in his estimate, remarkably close—the Superintendent gave an estimate of 15 tons as the amount of coal consumed by the engine with the present train. That came two or three days after the estimate had been made according to Mr. Shurtleff's formula, and the figure obtained therefrom was 14.94 tons.

Of course, the question of the most economical train loading brought in a great many things, among them the most economical grade. For instance, the 4000-ton-train would add about two hours time by the calculation, and it would increase the load by 50 per cent. It would add 15 per cent. to the time taken to get the train over the division. With a long division that might be a serious detriment, and might neces-

sitate dividing the division into a short turn-around, with two-thirds of the division, about ninety miles, as a straight division. It was suggested as advisable to figure on hauling the longest train possible over the present division of 130 miles, and that the calculations should be tested—as to the time necessary between stations for the present lighter trains—so that we might have greater faith in believing that the calculations as to future trains would pan out. That is a formula we used and applied in a practical way.

Mr. F. S. Stevens:—I merely want to say that I think the last words of the last speaker's remarks were well put, as to the "practical way," because there are so many questions involved. One of the principal questions is interference. The tonnage rating that is worked out absolutely correctly, which will give the best results and move the greatest tonnage in the least time, is indefensible in many cases, because to put that tonnage over the road means that you cannot put anything else over it. The local freight and the passenger service must be put out of commission. The tonnage trains can only move to the limit of the sidings, and they must have a limit of speed, and if they get into a hole in some place on account of the preferred service, they cannot get out. All these things have to be considered. I think that remark by Mr. Howard was very well timed.

Mr. Shurtleff:—This is all very interesting, but when we come to study the questions of economics of railway location, we must also study the problem of the conduct of transportation. The province of this Committee, however, is to study and so far as it can, furnish formulas for determining this question of economy in conduct of transportation, not necessarily figuring which will be the least or the greatest tonnage that can be economically handled in a train. After we have furnished the data, the transportation department can use it, or we can use it for them; but it is for us to furnish the necessary data.

The President:—The question is the adoption of the revision of the Manual, conclusion 2, page 436, that it be changed to read: "Numerous tests demonstrate that there is no absolute value for train resistance. For practical purposes freight train resistance can be considered constant between velocities of 7 and 35 miles per hour."

(Motion carried.)

Mr. Shurtleff:—Conclusion 3 of the Manual reads: "It is recommended that for freight train resistances between seven and thirty-five miles per hour the formula,

$$R = 2.2T + 121.6C,$$

be used for comparing freight train ratings on different lines and grades.

R = total resistance on level tangent.
T = total weight cars and contents in tons.
C = total number of cars."

Page 436 of the Manual: We propose to adopt a new conclusion 3, taking the place of conclusions 3 and 7. Conclusion 7 of the Manual reads,

page 437: "Train resistance is greater in cold weather than in warm. Per cent. of rating on account of variation in temperature, as shown in following table, is recommended for use in comparing new lines, and not for tonnage rating." And the table is given. We now propose to change this conclusion (see page 618 of the Bulletin) to agree with Mr. Begien's conclusions shown there, conclusions from dynamometer tests, except that we desire to embody his No. 2, which says, "These formulas should be used to represent the resistance of a train that has been in motion at least fifteen minutes." We propose new conclusion 3 to read, as Mr. Begien shows it, down to and including D. Then slightly to change the reading to "The following formulas are practicable where train has been in motion at least fifteen minutes." Then give the formula for A rating which is the same as the present formula given in 3, or practically the same; the formula for B rating, the formula for C rating, and the formula for D rating. These give the ratings for different conditions of temperature. Then insert the table shown on page 615 of the Manual. In that way we cover in the one conclusion what was covered in the two conclusions at the previous meeting, and as I understand from Mr. Begien these changes in rating are made from the extensive experiments which they made covering different temperatures.

The President:—Is Professor Raymond in the room? If so, we would be glad to hear from him. Mr. L. C. Fritch, have you any comment to make on this?

Mr. L. C. Fritch:—On page 618, (2) "These formulas should be used to represent the resistance of a train that has been in motion at least fifteen minutes." I cannot see that that is practicable. How are we going to get this train in motion the first 15 minutes? I cannot see that there is any practical use in that. Of course, it could heat up the journals, but we could not put on additional tonnage after the train had been in motion fifteen minutes. So of what use is the resistance at that time? It is probably well enough for information, but I cannot see that it is of any practical value to us.

Mr. Shurtleff:—Mr. Begien states on page 618: "With reasonable ratings of the power, starting resistances are negligible in warm weather. The engine must have a greater margin in cold weather, and when starts have to be made on ruling grades (especially when they follow long stops), extra allowance should be made."

Mr. Brooke:—As I understand the adaptation of this formula to actual practice, a certain speed will have to be assumed and that would be the speed that probably would be attained on the ruling grade after the train had been in motion fifteen minutes. In starting, of course, and for the first fifteen minutes of the run, if the run during that period is on the ruling grade, the train would proceed at a considerably lower speed than the assumed speed, but that lower speed for a period of fifteen minutes would not appreciably affect the running of the train over the division; so the value of the formula would not be affected.

Mr. Shurtleff:—The rating as given should have two things that govern; the time allowable over the district, and the ruling grade. The time allowable over the district would fix the speed on the ruling grades, and this speed would not in many cases fall below six miles per hour, and more often it would be eight and ten. At ten miles per hour the locomotive has a great deal less tractive power than it has at five miles per hour. In spite of the fact that we have in the past assumed that the locomotive could work with the reverse lever down in the corner notch, up to eight or ten miles per hour, we have yet to find a fireman who can fire enough coal in the modern locomotive, with its three thousand or more feet of heating surface and fifty to eighty square feet of grate area, and make steam to fill the cylinders at full stroke for speeds of eight or ten miles per hour. In our Western service with a consolidation locomotive such as we now have, we find it is a rare thing that a fireman can fire the locomotive properly so as to give steam with a reverse lever in the corner notch above five miles per hour. Therefore, when you get to working at 7½ or 8 miles an hour, your drawbar pull is much less and with the starting resistance in the early few minutes of the run the locomotive has greater power, while in all probability, and in fact the resistance is higher until the journals get warmed up; and that is a point that is really negligible, if we properly take care of the question of grades at stations. I do not think it would make so much difference with a mere stop for signal, where the journals would not have a chance to cool down.

Mr. John G. Sullivan (Canadian Pacific):—I think there is another reason that has possibly been overlooked, why this note should stand. It is unfortunate in a great many cases that the operating department and the engineering department do not work closer together.

If the Superintendent is not an Engineer and wishes to demonstrate that the Engineer is wrong and that his ratings are too high, he can very often make his wish good by showing a President or General Manager that the full rating as compiled by the Engineers cannot be taken out of terminals on maximum grades. If the Engineer's argument that he did not figure they would be able to make ten or fifteen miles an hour at starting in cold weather can be backed up by the approval of the Association, it will have its effect with the President or General Manager in question. As has been brought out by two or three other gentlemen, the engine can use greater tractor power for ten or fifteen minutes than it can hope to maintain over long grades, or if the country is very cold, a pusher can be put on to start out of terminals, and this note appears to have a great deal of value in pointing out exactly what is meant by full rating and showing that we do not expect engines to haul full rating when the cars are cold. Another point about this Committee going too far in getting into the other fellow's department, I do not think they can go too far. Take a practical case: Suppose we have a Superintendent who wants to load everything up to the very last notch, and we have some short 0.4 per cent. grades that could possibly be reduced to

0.3 per cent. We do that work and spend thousands of dollars on a division. The next Superintendent comes along and says: "We are loading too high; we are going to load at a 10 or 15 per cent. reduction." The chances are that the money you have spent on the grade reduction has been thrown away for the reason that if the former Superintendent was loading light, the loads could be carried over the short 0.4 per cent. grades. I am very much opposed to any restrictions of this Committee in the way of figuring out economics and going into the costs, and also the method of transportation. That problem would have to be solved by each road itself. They must get together with the operating and engineering departments, but the general information that this Committee can give should not be restricted.

Mr. A. J. Himes (New York, Chicago & St. Louis):—Mr. Sullivan's remarks give me sufficient courage to get up and say what I can to reinforce what he has said. It seems to me very clear that it is the function of the Engineers to plan, lay out and build the railroads, and in so doing we are certainly expected to forecast with reasonable accuracy what the performance of the railroads will be after they are built. Now, if some person, looking at the problem from a different angle, or a different experience, is able to get results out of the roads different from those which have been forecast by the Engineer, then the Engineer has failed. He has failed because he has not known all that might be done on the railroad and therefore has not built it in accordance with the future operation of the railroad. To me it seems, pursuing the subject in this line, that it is primarily the duty of the Engineer to be thoroughly posted with the work of the operating department as it is actually done, and to learn from it all that he can, and to offer his assistance in any case where it appears that the best results are not being secured in the operation of the road. It seems to me that in many cases a division has been made between the different departments of a railroad that is too sharp, that is unwise. The whole organization of a railroad is created for the purpose of getting trains over the road, and earning an income, and primarily this point of view is that which the Engineer should hold, as well as others. The particular development of the present generation in all kinds of economic work is with co-operation. The need of co-operation has been pointed out many times in the last half dozen years. The great secret of success in large enterprises is to bring about accurate and hearty co-operation between the many units of an organization. I think, with that in mind, if the changes are not too radical, it might we well if we had, on a railroad, first an operating department, and then in place of an engineering department, what we might for convenience term a co-operating department. (Applause.)

Mr. A. W. Buel (Consulting Engineer):—The formula for *rating* at the different temperatures may be all right for operating conditions, but for economic comparisons will it not be necessary to assume or find the average temperature? In the computation of an economic comparison of alternate locations, we have to take the average for a year or a

series of years and the speaker thinks it would be well for the Committee to add what they consider the averages should be.

(By letter) :—The writer thinks the Committee will agree that their most useful and lasting work will be that of collecting data and putting it in shape to be available to those engaged in economic computations. The question of average temperature in different sections is purely one of statistical data, which the writer believes the Committee could collect and arrange, from records of the weather bureau and other sources. When an economic comparison problem comes up there is rarely sufficient time available to collect and digest such data. Certainly such data should be segregated for different sections according to geographical, topographical and climatic conditions. Moreover this study should include the effect of moisture and the difference if any in the effect of low temperatures in moist and dry climates. In fact the combined effect of climatic conditions on locomotive rating should be considered. If segregated for prairie, mountain and coast and for North, South, East and West, there would be some rational basis for the exercise of judgment in any particular case.

The formulæ presented by the Committee seem to be based on the assumption that climatic conditions affect train resistance but not tractive power. While they may give practically correct results it is probably true that tractive power is also affected to some extent by temperature as it is by frosty or wet rail and other causes, such as number of months locomotive has been out of the shop, etc.

In his report on location of Western Pacific Railway, Mr. Virgil G. Bogue, Member American Railway Engineering Association, adopted 85 per cent. of the maximum computed rating as the average service rating. This resulted from an extended study of the subject and of all procurable data, made by the writer under Mr. Bogue's direction.

On the whole it would seem that the Committee could render a more permanent and lasting service by confining their attention for the next year or two to collecting and arranging data, on which they have made a most commendable beginning—leaving the development of formulæ until such time as their data can be thoroughly digested and discussed.

Mr. Shurtleff :—That is something that would vary in the different sections of the country. The Engineer who is working in one section of the country can determine from the statements of the Weather Bureau, which he can easily gather, the average number of months in which the temperature is above the 35-degree point, and the others, and by that means he can determine the average loading or percentage of loading as compard with the A temperature, but it would vary in different sections of the country. It is supposed that any Engineer who is using this has some judgment. We cannot form judgment for him. It is supposed that he has some judgment in the use of this formula.

Mr. J. L. Campbell (El Paso Southwestern) :—I believe that a safe rule for a Locating Engineer to follow is to assume that the operating department will make a proper and efficient use of the plant that the

engineering department gives for the conduct of transportation. It has been my observation and experience that Engineers, where they make errors, are likely to make them on the side of failure to recommend the expenditure of the larger amount to secure one of the fundamentals of economic transportation, which is the lower grade line, and that they also err, if they err at all, upon the side of failing to spend enough money on the minor details, such as the alinement and the lighter curvature. I have known cases where, even before an important case of construction was completed, it became evident that an error had been made in not deciding upon the larger expenditure to secure the lighter grade, the better alinement, and other innumerable details that go to make up a first-class operating plant.

Mr. L. C. Fritch:—Respecting the previous speaker's remarks about the Committee establishing some average conditions, I take it we can rely upon these figures given us by the Committee, as not only average conditions, but average practical conditions, and it seems to me to assume some average condition would not be as fair as to take the actual results deduced from practice. There are various temperatures given, from 35 degrees Fahrenheit to temperatures below zero. The only suggestion that I might make is that there are temperatures as low as 40 and 50 degrees below zero in the Northwest, where operations are carried on, and it might be necessary to make allowance for those low temperatures.

Mr. Shurtleff:—You possibly misunderstood my remarks. When we are making estimates with reference to proposed location, we are making estimates on the average work. Now, through the great bulk of the year, the transportation man will know that the A rating would apply. There will be a short time during the year when possibly the B and C and D ratings would apply. With the table which is given on page 615, the Engineer will be able to reasonably determine whether 95 per cent. of the A rating could be hauled through the year, or the average of the year would be 80 or 90 per cent. of the A rating, or whatever it may be, using this formula which we lay down.

Mr. L. C. Fritch:—The only point that I want to make is that it does not cover all the operating conditions throughout this country and Canada. I believe there ought to be one additional class of rating for the lower temperatures.

The President:—The Committee will take note of that in a further report. If there are no further remarks on this question at this time, in order to expedite the work of the Committee, the motion before the house is that conclusions 3 and 7 be eliminated from the Manual, and that in lieu thereof the matter on page 618 of the Bulletin, entitled, "Conclusions from dynamometer tests" and the table at the top of page 615 of the Bulletin be substituted in the Manual. Are you ready for the question?

(Motion carried.)

Mr. Shurtleff:—Conclusion 4 of the Manual reads: "(4) In order to equalize resistance on curves and tangent, curves should be ordinarily

compensated .035 per cent. per degree of curvature. Effect of curve resistance is dispelled more slowly at slow speed than at high speed." In place of this the Committee desires to have the following substituted:

"(1) Compensate .03 per degree:
  (a) When the length of curve is less than half the length of the longest train.
  (b) When a curve occurs within the first 20 ft. of rise of a grade.
  (c) When curvature is in no sense limiting.

"(2) Compensate .035 per degree.
  (a) When curves are between one-half and three-quarters as long as the longest train.
  (b) When the curve occurs between 20 ft. and 40 ft. of rise from the bottom of the grade.

"(3) Compensate .04 per degree:
  (a) Where the curve is habitually operated at low speed.
  (b) Where the length of the curve is longer than three-quarters of the length of the longest train.
  (c) Where superelevation is excessive for freight trains.
  (d) At all places where curvature is likely to be limiting.

"(4) Compensate .05 per degree wherever the loss of elevation can be spared."

Mr. L. C. Fritch:—I suppose the Committee intends to take into consideration under (c) the degree of curvature; that is where they say, "when curvature is in no sense limiting." I was going to raise the point that the degree of curvature is not taken into consideration. I assume that it is intended that will cover that point. I think the degree of curvature has some influence upon the resistance.

Mr. Shurtleff:—What would Mr. Fritch suggest to take its place?

Mr. L. C. Fritch:—I would suggest that a certain maximum degree of curvature be specified.

Mr. Shurtleff:—What maximum and why? "When curvature is in no sense limiting," that is, when the grade resistance plus the curve resistance would in no sense equal the limiting grade of the district.

Mr. L. C. Fritch:—I do not know whether the Chairman understands the point I wish to make. This, as I understand, refers to the compensation of the grade for curvature. Now I think the rate of compensation would be different where the degree of curve is different. I do not believe it would be same for a six-degree curve as it would be for a two-degree curve.

Mr. Shurtleff:—You mean the compensation per degree?

Mr. L. C. Fritch:—Yes.

Mr. W. McC. Bond (Baltimore & Ohio):—It seems to me this is clear, for the reason that there should be no compensation on a curve where the grade is level, where you have a .3 or .5 per cent. grade further on. It is clear in the way it stands.

Mr. L. C. Fritch:—We have conditions where we have six degrees of reverse curves on limiting grades. That is the condition I want to cover.

Mr. Shurtleff:—A six-degree curve on a limiting grade can never occur in a place where the curvature is in no sense limiting. We are speaking of curvature on low gradients, where the curve resistance, plus the grade resistance on tangents, could in no sense equal the limiting grade of the engine district. The only object in compensating a grade in such a case would be to produce a more uniform work of the locomotive on its ascending the grade. It is pretty well established fact that if you can have uniform work of the locomotive you can work the locomotive more economically, and that would be the only object in compensating a curve, where the curve resistance plus the grade resistance would not exceed the ruling grade.

Mr. J. B. Jenkins (Baltimore & Ohio):—There seems to be a considerable difference of opinion, based on different results of tests, as to whether degree of curve increases the resistance per degree of central angle, or whether it decreases it. In general, it seems that if you disregard all other conditions, a ten-degree curve will apparently require less compensation per degree than a two-degree curve; but I believe if we consider other conditions we will find the case to be quite the opposite. I think the true reason why the ten-degree curve seems to require less compensation per degree is that the speed at which the freight train passes over the ten-degree curve is more nearly that for which the rail is elevated, while with a two-degree curve the rail is liable to be elevated for fast passenger service and the freight train goes around it at a much slower speed, resulting in greater relative friction. The coning of the wheels undoubtedly has some influence, and I believe if all facts are taken into consideration it will be found that a two-degree curve offers less resistance, from curvature alone, per degree, than the ten-degree curve does; that the principal factor governing the rate of compensation should be the relation of the elevation of the outer rail to the elevation required for the average speed of freight trains. For example, assume a train 2500 ft. long, passing over a track on which there are two curves, one a four-degree curve 1000 ft. long, central angle 40 degrees; the other a two-degree curve 2000 ft. long, central angle also 40 degrees. According to the Committee's recommendation, the four-degree curve, being of less than half the length of the train, should be compensated at .03 per degree, a total compensation of 1.2 ft. for the entire curve; while the two-degree curve, being of more than three-quarters the length of the train, should be compensated at .04 per degree, a total compensation of 1.6 ft. for the entire curve. Bear in mind that the central angle is the same for the two curves. I greatly doubt the correctness of this conclusion, for undoubtedly there is more friction in swinging the truck on entering a four-degree curve than there is on entering a two-degree curve, and again in leaving the curve; the coning of the wheels has an effect in reducing resistance all the way through the curve; I believe if all conditions were taken into account, that these figures should be more

nearly reversed; that it should be more nearly .03 for the two-degree curve 2000 ft. long, and .04 for the four-degree curve 1000 ft. long. I think the Committee has failed to take into consideration the one most important factor in determining the rate of compensation, and that is the relation of the elevation of the outer rail to the elevation required for the average speed for freight trains.

Mr. C. P. Howard:—The compensation is per 100 feet. For one hundred feet the degree of curve and the central angle are the same. Thus a 1.00 per cent.-grade compensated 0.04 per degree for a two-degree curve, would be 0.92 per cent.

Mr. Brooke:—As has been mentioned before this morning, the Committee at one period of its existence experienced a great deal of trouble in getting data with which to work. As I understand it, the data from which this report has been compiled was secured in tests of actual practice under actual conditions—no particular attention was paid to the makeup of the trains on which the tests were made, they were simply trains made up in the usual course of operation. They ran over a great many divisions, a great many different curves, grades and other conditions. The conclusions have been reached from these actual results, and unless other information is available for the Committee, I am highly in favor of adopting the conclusions reached, for I believe they are based upon the best information available, and therefore should be respected to that extent. Of course, if other information is available, I feel certain that the Committee would be glad to have it.

Mr. Shurtleff:—This Committee will never reach anywhere. We will simply be up in the air, until we fall, if we do not reach some conclusions. Three years ago we reached a conclusion. There was a great deal of discussion on the floor of the convention at that time with reference to this conclusion as it now exists in our records. The conclusion as brought in to-day we believe is an improvement on that conclusion. If we get cut out of this conclusion as it is presented to-day, we will have something worse left in the Manual. We believe if you will adopt some conclusion to take the place of the conclusion that exists in the Manual, something in the line of this conclusion, we are going to improve, and that later we can come in with a modification of this conclusion.

The President:—The Chair wishes to add one point to this discussion, and ask a question of the Chairman. Conclusion 4 reads: "Compensate .05 per degree wherever the loss of elevation can be spared." Is it to be assumed from this that the Committee believes it good practice to permit all trains to run more easily around curves than on tangents?

Mr. Shurtleff:—It was brought out three years ago that there are places where every foot loss of compensation runs into big money at the summit where you are working on long supported grades. Where such a condition does not exist and we can afford the .05 per degree, we are helping out our freight service. We are compensating more nearly so as to help the freight service with reference to the superelevation.

Ninety-one per cent. of the mileage of this country is single track mileage, and therefore when curves are elevated for safe speed of down-hill passenger traffic, up-hill freight traffic is handicapped by that superelevation, and if we can easily spare the additional compensation, we think it will help out the freight service.

Mr. L. C. Fritch:—I do not want to be put in the attitude of discrediting the work of the Committee. That is farthest from my thoughts, but referring to the remarks of the Chairman, that if we do not adopt this recommendation of the Committee, we will leave something in the Manual which is worse, I agree fully with that statement, but is it not advisable to take into consideration all the elements, and it seems to me that one of the important elements in the compensation of curvature is the rate of the degree of curve. Is the compensation the same for a three-degree as six-degree curve or higher? I think that is valuable information for us to have. If the Committee feels that this report should be adopted as recommended, I would suggest that next year they take that matter into consideration.

Mr. W. M. Camp (Railway and Engineering Review):—I am much in sympathy with the views of the Chairman of this Committee. I have known committees to work faithfully and well for a number of years without getting anywhere. They would report one way one year, and that would not suit some of the members; and then they would change their report to conform to the criticisms offered, only to change back again the next year, to meet the views of those who might chance to express them with possibly greatest emphasis at the time. In this way the Committee would be kept jumping first to one side of the fence and then to the other.

It seems to me it is only a question as to whether these formulas reported are an improvement over those now in the Manual. Of course, what goes into the Manual should be well-digested and should be reasonably accurate, but as we have seen with much of our work in general, nothing passed by this Association is of a hide-bound character or like the laws of the Medes and Persians—it can be changed; and the Manual is being changed constantly. I think that is a good way to secure something which will in the end be finished and in the best form possible, even if it cannot be said that it is quite perfect to start with. I think it is reasonable procedure to first get something into the Manual which is the result of the best studies of the Committee, providing it bears up well under discussion, and then improve on that from time to time, if we can.

Mr. L. C. Fritch:—I would take the other side of the argument advanced by the speaker. I think these meetings are for the purpose of discussing these reports. If we take the reports of the committees as they are presented to us and adopt them, we need not come to this convention. I think in a multitude of counsel there is wisdom, and I believe in discussing these things to the fullest extent.

Mr. Shurtleff:—I think Mr. Fritch misunderstood me. I am not opposed to the changing of this conclusion, I am not opposed to discussion, but I do want constructive criticism. If the conclusion is to be turned down, I want something to be substituted for it, to cover the grounds which the conclusion tries to cover.

Mr. Camp:—That is just the point—if this is an improvement on what is already in the Manual, let us have it; or if someone has anything that is better than this let him put it forward.

Mr. John G. Sullivan:—I think there is a misapprehension here. I do not think Mr. Jenkins interprets these instructions as the Committee does. He brought out the example if he had a two-degree curve for 40 degrees, that would be 20 stations long, and a train of 25 cars; that would not come under the first clause at all, that would come under clause 4. For a four-degree curve, that would come in clause 1, because it would be less than half the length of the train. The argument of Mr. Jenkins and the Committee's recommendations are identical.

A third point was brought up by one of the members of the Committee in this discussion, and I think he is wrong when he speaks about this .04 ft. per degree per 100 ft. I do not care what table you have, if you had an 80-degree of angle to overcome, and you do it with a 15-degree curve or a two-degree curve, or with a one-degree curve, or with a 100-degree curve, you will have the same amount of compensation. It is per degree.

Mr. C. P. Howard:—I think the compensation is generally figured per 100 ft. If you have a 1 per cent. grade and compensate for a two-degree curve, you would make it a 0.92 per cent. grade.

Mr. John G. Sullivan:—It works out that way.

Mr. C. P. Howard:—That is, the degree of curve and the central angle are the same for 100 ft.

Mr. John G. Sullivan:—With the same central angle if you have 40 degrees of central angle, and you use table 3, you will compensate 1.6 ft. That will be the loss of elevation you are making on account of the curvature, and it makes no difference what the degree is. The rate of grade going through the curve will depend on the degree of the curve. I think the Committee has properly stated the compensation as per degree.

I am heartily in sympathy with the report of the Committee because they have given us four different rates of compensation.

Mr. Jenkins:—Mr. Sullivan has evidently misunderstood me, and I am afraid the rest of the convention will do so. What I referred to was the fact that for the two-degree curve, the Committee would compensate, under clause 3, 40 degrees of central angle at .04 per degree, which would make a total compensation of 1.6 ft. For the four-degree curve they would compensate, under clause 1, at .03 per degree, which would give a total compensation of only 1.2 ft.

I do not doubt that the conclusions of the Committee are in seeming accordance with the results of dynamometer tests and I would call attention to the beginning of my remarks wherein I referred to the fact that

a great many observations and tests would seem to indicate some such variation, but I do feel that the reason for it is not that the increased degree of curve decreases the rate of compensation in itself, but that the increased degree of curve taken in itself would rather increase the rate of compensation. The apparent decrease in rate of compensation for the higher degrees of curves is due to the fact that the train runs over the curve at a speed more nearly that for which the rail is elevated. I think as a general proposition that this rule of the Committee is a great improvement over what we had before, but the Committee has simply failed to go far enough and include the most important factors; and if it is permissible I would amend the motion to adopt these conclusions, and make a motion that these conclusions be adopted and published in the Manual, and that the Committee be requested to resume consideration of the subject and enlarge upon it.

The President:—That is the general instruction to all committees, that the matter of revising the Manual is always before them. The Chair thinks it is not necessary, therefore, to put that in a motion.

Mr. Jenkins:—I will recall that. There is one other remark I wish to make; under the third clause: "(a) Where the curve is habitually operated at low speed," .04 per degree is provided, which is one of the higher rates of compensation. As it stands that is usually a safe rule, but when a curve is habitually operated at low speed and there are no fast trains, so that the rail can be elevated for slow speed, then the lowest rate of compensation would be entirely permissible. For instance, if you have a line used entirely for freight at an average speed of 15 miles per hour, and you can elevate the outer rail on your curve for only 15 miles per hour, you will find your required rate of compensation is very low; while if you take a line which is operating for passenger trains at 60 miles an hour and also freight trains at varying speeds of 10 to 20 miles, you will find the required rate of compensation is higher; these things should be taken into consideration by the Committee.

Mr. Shurtleff:—Speaking of track used solely for one class of traffic, I will say that only .6 of 1 per cent. of the railroad mileage of the United States is made up of four-track roads, and we have really made our conclusions to suit the 99 per cent. of railroads which have single or double track road.

Mr. J. L. Campbell:—I ask the Committee to state the reasons for making the curve length a factor in determining the rate of compensation.

Mr. Shurtleff:—There is only a portion of the train being subjected to the resistance at one time, and the drawbar pull of the locomotive is constant. If the whole train was subjected to the resistance it would mean that each ton of the train was subjected to that resistance, but in cases where only half of the train is subjected to that resistance, worked out as by Mr. Begien, we think a less resistance would be suitable in each case.

Mr. J. R. W. Ambrose (Grand Trunk):—I would like to see two words added to clause (c) in conclusion 1: Oftentimes in laying a

grade line a few feet of elevation makes a great difference in the necessary expenditure, and I cannot see why it is imperative to compensate a grade for curvature when the virtual grade is less than the maximum adopted by the company, which is .04 per cent. on the Grand Trunk. Therefore, I would like to add the words, "if desired, when curvature is in no sense limiting."

Mr. Shurtleff:—The object of compensation is to attempt to make equal resistance, or make the resistance on the curve equal to the resistance on the tangent, that is, reduce the curve grade so that the resistance on the curve grade would equal the tangent resistance.

Mr. S. S. Roberts (Consulting Engineer):—Yesterday a point of consistency was brought up. On page 621, paragraph 3, the word "superelevation" is used. Would it not be better to drop the word "super?"

Mr. Shurtleff:—The Committee will accept that.

Mr. Brooke:—There is one remark I wish to make for the information of the Association, and that is that the dynamometer tests referred to in the paper by Mr. Begien embraced almost every conceivable class of line and traffic. The tests were made on lines having from 2 to 2.2 per cent. grades, with curves as high as 14 degrees, and they were made over .3 per cent. lines, with maximum curvature of four degrees, on which there was no passenger travel whatever. They embraced other high-speed lines having curves of five and six degrees, with mixed traffic, and practically level lines having some curves of as high as nine to ten degrees, on which the speed of passenger trains was high, and the speed of the freight trains was low.

Mr. Edward Gray, Jr. (Chesapeake & Ohio):—It has been suggested that compensation for curvature is needed only for maximum grades. I believe this opinion is incorrect, and that the Committee deserves credit for prescribing compensation for all grades. It does not seem so certain that a lower rate of compensation should be used on the minor grades. There are cases known in which the load for slow freight trains has been limited by neglecting to compensate on grades thought too light to want it; and the future will bring out more of them. The original limiting grades of a railway may be removed by relocation or overcome by helping engines, leaving some of these despised minor grades to limit the performance of engines. Besides, almost any considerable section of a railway may some day become part of a train division in conjunction with some new line or branch, or other railway, and the grades of this section may become the limiting grades for such runs. On lines of generally light grades and sharp curvature, hauling heavy freight, this matter is especially important.

Mr. M. L. Byers:—I want to offer a suggestion to the Committee. My idea is that curve resistance depends on three principal factors. The first is the degree of curvature, the second is the relation between the length of the curve and the length of the train, and the other is the superelevation of the curve. The formula which the Committee has offered us seems to cover the first two factors. I suggest that the Com-

mittee keep in mind the matter of looking into the question of the effect of variation in superelevation on the curve resistance in the future.

Mr. E. E. R. Tratman (Engineering News):—It seems to me that one very important feature of this report is that it shows the practical advantages and economies which may result from scientific refinements in track work. For years it has been assumed that track work must be more or less rough and approximate. That is true to some extent, but not to the extent to which it has been assumed. It is true that the rain will soften the roadbed, the trackmen will disturb the ballast, and the effect of the traffic will be to settle the ballast and compress the roadbed. As shown in the report, the existing grades are not the normal or intended grades, due to these disturbing influences; so that the actual operating conditions are not those which are assumed or supposed to exist. But modern conditions of railway operation are demanding increased efficiency of the railway as a machine, and there is no doubt that one step to such efficiency lies in putting and keeping the road in best condition to handle its traffic. The business of the railway is running trains to carry traffic. Increased economy and efficiency in this business requires improvement in both the road and its equipment, and the maintenance of proper relation between the road and the train. Greater attention will be required to the railway itself, and keeping it in its relation to the traffic which it is required to handle. For these reasons I am in favor of the Committee's resolutions, if only as representing an ideal to be aimed at, and subject to modification. There is one point I would like to suggest, however. With grades so carefully adjusted to traffic requirements, maintenance of these grades becomes an important matter, and it is open to question whether under the everyday conditions of traffic and maintenance work the carefully adjusted compensated grades could be maintained regularly with the ordinary forces. According to these different rates of compensation, as recommended by the Committee, there might be different compensated grades on the same division. Could they be maintained in sufficiently close approximation to the original and exact grade for any considerable period of time by the section forces, and under the disturbing influences of traffic, weather and track work; or must some further advance be made to meet the requirements for railway maintenance of way?

Mr. J. L. Campbell:—Before this Association decides to adopt these recommendations, I want to go on record as saying that I do not believe the curve length is a proper element to take into consideration in determining the rate of compensation. The curve resistance is independent of the tangent resistance or of any part of the train on the tangent. The object of curve compensation is to make the resulting combined curve and grade resistance on the curve equal to the grade resistance on the tangent. These elements are not affected by the length of the curve.

Prof. W. G. Raymond (Iowa State College):—I want to call attention to two points in response to the Chairman's invitation for constructive criticism. I want to emphasize the point made by Mr. Fritch.

I think, speaking theoretically—of course I cannot speak from practical observation—that curve resistance varies with the degree. Therefore, the compensation, to be theoretically exact, to produce the effect that the Chairman of the Committee says he wishes to produce, namely, a constant pull on the drawbar, or at least a constant effort of the locomotive, should vary with the curve resistance, and I think it is pretty well established that curve resistance must vary with the degree of the curve. I think this must be evident from the fact that a large part of the resistance is due to the twisting of the truck on the track, and that means simply the friction between the wheel and the rail, which must be largely independent of the degree of the curve. This element being divided by the degree of the curve must give a less resistance per degree for higher degrees.

Of course, I think, the Chairman, in answer to the question of the President, went back on his statement that he wanted to secure a constant effort of the locomotive, because he said whenever it is convenient we should have an excess of compensation so as to make the work easy for the freight trains.

The other point I have in mind is this—in these days we are devoting a large part of our effort to the betterment of the submerged tenth, and it seems to me the submerged tenth that have four tracks are as well entitled to consideration as the 90 per cent. of the roads who have only one track, and therefore it seems to me that in the Committee's report, when it is finally made up, there should be one rule for one-track roads and other rules for four-track roads; the Committee should take notice of that fact in making its conclusions.

I am not speaking against the adoption of the Committee's report, because I think the report this year is an improvement on what we find in the Manual.

Mr. W. M. Camp:—I do not understand the point which several of the speakers have been trying to make by way of criticising the Committee for not taking into account "degree of curvature in relation to resistance." In these three rules which the Committee has presented, the compensation is figured with relation to the degree of the curve. Perhaps they intend to propose that the compensation should not be uniformly varying with degree of curvature. If that be true, I would like to inquire if anyone present can refer to investigations or tests which show the resistance to be otherwise than uniformly varying with degree of curve.

The President:—Are you ready for the question in favor of adopting for publication in the Manual, in place of conclusion No. 4, as it appears in the Manual, the matter at the bottom of page 620 and top of page 621 headed "Conclusions?"

(Motion carried.)

The President:—We will now turn to the conclusions on page 587.

Mr. Shurtleff:—These conclusions are in reference to the present

matter published in the Bulletin and attempt to lay down an approximate method of analyzing the maintenance of way expenses, particularly those expenses which vary with the volume of traffic.

The President:—These conclusions should not call for as much discussion as if they were to be published in the Manual.

Mr. Shurtleff:—These are presented to aid in the analyzing of the expenses referred to, but this Committee cannot feel it has hit the exact method. We believe, however, we have made a long stride toward a proper method of analysis. I move you, Mr. Chairman, that conclusions 1, 2, 3 and 4 be adopted as information.

(Motion carried.)

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—I ask the Committee how they found out that one ton of passenger train does more damage to track than one ton of freight train, or that one ton of passenger car and contents produces approximately the effect of two tons of freight car and contents. I do not believe, as a general proposition, that the passenger train is twice as severe on a track as the freight train. It depends somewhat on the speed. I believe that the passenger cars are kept in better condition than the freight cars, and have fewer flat wheels. The damage to the track which causes repairs depends on the speed, and that should be taken into consideration.

Mr. W. G. Atwood:—For the information of the Committee and the Association I would say that about three years ago Prof. Hatt at Purdue University started in to develop a machine for the purpose of measuring track deflection. He has used our tracks where we have some 3 to 4 per cent. grades, and some 1 per cent. grades, double track, 90-lb. rail, in fairly good condition. He has not published anything so far because much of the work has been in the development of the machine. I have seen some of the tests and a great deal of the work has been in the way of calibrating and developing, but I believe that the Committee, by communicating with Prof. Hatt, might develop something along that line. Perhaps that was his idea in developing the machine.

The President:—Prof. Hatt is here. We would like to hear from him.

Prof. W. K. Hatt (Purdue University):—I have nothing to say this morning; I have just started in on my experiment.

Mr. L. C. Fritch:—I have no constructive criticism to make in this case, but it does seem to me before we adopt even as information a conclusion that may be as far-reaching in its effects as this we ought to get all available data on the subject. We all know that efforts are being made to determine the cost as between passenger and freight service. If we establish a principle here that it costs twice as much to maintain track for passenger service as for freight service, I think we want to be very sure of our ground. It seems to me that it is possible to get some accurate data on this subject. There are many lines operating in this country which have separate passenger tracks and separate freight tracks, and I believe before we adopt a conclusion of this kind, which

is very largely a matter of opinion and judgment, that we ought to get all the available data we can on the subject.

Mr. W. M. Camp:—The Committee says: "Until data are available to correctly estimate the relative damage, it is recommended that the following ratio be used in estimating the effect of traffic," etc.—I wish to ask the Committee whether it had some information on which to base this conclusion, or did the Committee just guess at it?

Mr. Shurtleff:—The Committee did not have any information except to sit down and study the questions as far as they could consider them. It is just merely a guess. This is the most important feature of our report; it is the part which should be discussed most freely, and yet this Committee is willing to have this whole subject turned right back to it if some of the representatives of the roads here will get up and assure us that they will give us information on this subject, derived from practical experience, within a year or two. It is a big subject, and while we do not want to say that passenger traffic costs twice as much as freight traffic, we do mean to say that we think that one ton of passenger train does double the damage of one ton of freight train. I must frankly say that Mr. W. J. Wilgus, in making his criticism, brings out some splendid points, but we considered those points and also some points on the other side, which he did not bring out. I can go Mr. Wilgus one better on his side; as I brought up a while ago, on single track main line our curves are elevated for safe speed for downhill passenger traffic, and on the uphill, with our maximum trains and heavy axle loads, as we are coming to them now in our locomotives, we are placing an unbalanced force on the track—in one case which I know of there was 7,600 lbs. added per wheel on the lower rail—and we are crushing the heads of those rails on a crooked line, and the freight traffic is doing far more damage than the passenger traffic to the rail.

There are a number of points also about passenger traffic. Mr. Rose spoke of the flat wheels. I have ridden on some suburban trains in the vicinity of Chicago—not on the Rock Island—with flat wheels, bobbing along at the rate of 45 or 50 miles an hour, and I believe that flat wheel is doing more damage to the track at that high speed than probably a dozen flat wheels on freight cars would do. The speed has something to do with it, because the impact will vary in some ratios to the square of the speed.

In my opening remarks I brought up the point that the passenger locomotives in their nosing have a greater effect in throwing out the track than the freight locomotives do. Even at the lowest speed of the freight locomotives, the unbalanced portion of the locomotive will have less effect than in the case of passenger locomotives.

Mr. C. F. Loweth (Chicago, Milwaukee & St. Paul):—I am in accord with what Mr. Fritch says. I think the Association ought not to adopt this conclusion. It seems to me it has a more far-reaching effect than that of the question of economics of railway location. The subject is up in many places as to the relative cost of freight service and

passenger service in the determination of proper rates. That question is being considered all over the country, and we should go very slow, as an Association, before we commit ourselves on a matter of this kind.

Further, it seems to me that some light can be gotten on this matter from the reports on the impact tests, and that would throw some light on the subject of the relative burden on the track of freight and passenger trains. I do not think we ought to commit ourselves in this matter.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—There seems to be some confusion as to the action which the Committee desires taken on this report. They have asked for its adoption as information. On page 4 of the Program will be found the different methods for considering the reports presented and the action to be taken thereon, and I suggest that the proper action to be taken is that under (b), paragraph 16, which reads, "Receiving as a progress report."

Mr. W. M. Camp:—I think this discussion is interesting. I have some doubt as to whether the conclusion under discussion should be adopted, but I admire the frankness of the Committee in regard to it. I do not think this Association could accomplish any better result than by going into a thorough study of the subject of the relation of wheel loads and speeds to wear and tear of the track. I presume that one consideration the Committee had in mind, in recommending these two rules in regard to the relative effect of a ton of passenger car and a ton of freight car, is that passenger trains are usually run at faster speeds than are freight trains. We know on some roads locomotives have been built for passenger trains that have had a pretty bad effect on the track, and we were not long in finding it out and the design of those locomotives had to be modified for that reason.

The Committee has put it up to the Association and frankly state that they guessed at these conclusions, more or less, but they have guessed at a thing which it is important for the Association to know something about. As far as I can find, everybody is guessing at the effect of increase of locomotive weights and freight-car loads on track, and I think it is about time we stopped the guessing and got at it in some reasonable way, that we found out actually what punishment is being inflicted on the track. If the operating men will not give to the Committee the data which it requires in order to form correct conclusions, what is the Committee to do? It has done what the Chairman said, guessed at it.

Mr. Shurtleff:—I think that Mr. Camp has hit the nail on the head. We have started on a method for determining these things, and we believe the method is a long step in the right direction. Now, we have been talking about adopting these conclusions—I think we have made a mistake in putting it that way; the matter should be received as information. The principal thing, however, is to bring before this Association the situation of this Committee. This Committee has got to stop work now on the advance study of this question until we get some means of going ahead and analyzing these accounts, and that is the point. We will be glad to receive all assistance from any of the roads that can be given

us, in order to determine this question. We will be glad to get away from the guessing side of it.

Mr. C. E. Lindsay (New York Central & Hudson River):—I believe we should not accept this information if, as stated, it is merely a guess. I am in position to give some information as to the relative effect of passenger and freight service on tracks. We have a four-track railroad, two tracks being devoted largely to passenger traffic, and two tracks being devoted wholly to freight traffic, although the passenger tracks are also used for high-speed freight traffic. If it was my guess, I would reverse the guess of the Committee. I think the Committee has been misguided by the effect of the train as a whole and the Committee has underestimated the effect of speed. In my opinion, the design and maintenance of passenger equipment is far superior to that of freight equipment. In the passenger equipment we have six-wheel trucks, with a very superior spring arrangement. In the freight service we have four-wheel trucks, and the spring arrangement is hard and rigid on the track.

Mr. M. L. Byers:—It seems to me that we could omit from the consideration of this question all reference to passenger or freight service. In my opinion, it is a question of speed. Many years ago the Louisville Division of the Pennsylvania Railroad put out what seemed to be a rather peculiar order, limiting the speed of the fastest freight trains to 60 miles an hour. I do not believe a fast freight train running at 60 miles an hour is different in its effect from a passenger train running at the same speed, and my experience with the relative cost of maintenance of track under high and low-speed traffic is that it depends mostly on the standard of the maintenance of the track as to the cost. The cost of track maintenance, as the result of deterioration under train service, is principally for surfacing, that is, the labor cost, and the labor cost of picking up a low joint, ⅛-inch low, is almost the same as picking up a joint ½-inch low. If you have trains running 60 to 70 miles an hour you must maintain the joints more nearly to a perfect level than on a track where the trains run 30 miles an hour. Any examination of an ordinary freight track will show that element is taken into consideration; that the maintenance is much less perfect in that case than in the higher-speed tracks. If, however, for any reason they should run any high-speed trains on these freight tracks, the difference I have referred to would be immediately noticeable and they would have to improve the condition of those tracks.

I think Mr. Fritch is right in calling attention to the undesirability of this Association taking too prominent a part in the question of segregation of costs between passenger and freight trains, and my suggestion is that feature should be ignored and the Committee should simply deal with the relation of speed and weight to the cost of maintenance.

Mr. Himes:—I wish to say in behalf of this Committee and in behalf of all committees, if Mr. Lindsay has information of the character that he has stated, he should have already given that information to the Committee, and it is to be hoped he will do so immediately.

Mr. Lindsay:—The conditions on our roads are these: Up until three or four years ago the passenger tracks were sacred. The freight train that got on a passenger track had to have a special license for doing so, but recently the density of traffic has increased to such a point that it has been necessary, in order to take care of the freight traffic, to run a great many freight trains, both slow freights and fast freights, on these passenger tracks, and the effect on the cost of maintenance has been very marked.

Mr. Byers calls attention to the sameness of cost in raising a small low joint and a very bad low joint. That is a question of comfort with relation to passenger trains and does not enter materially into this case.

The data we have been gathering this past year will be given to the Committee when it is available.

Mr. L. C. Fritch:—Mr. Loweth made a valuable suggestion, and I would add to that that we get from Dr. P. H. Dudley any information he is willing to give us in regard to his stremmatograph tests.

The President:—We have received conclusions 1, 2 and 3 as information. No. 4 is before you, to be received as information, or to be referred back to the Committee, if you desire to take such action.

Mr. Lindsay:—I move to amend that the conclusion be referred back to the Committee for further study.

(Motion carried.)

Mr. Shurtleff:—Mr. President, in view of the fact that conclusion 4 has been referred back to the Committee, I move that conclusion 5 also be referred back, as it depends on No. 4.

(Motion carried.)

Mr. Shurtleff:—I would ask you gentlemen who represent four-track roads to kindly assist this Committee as far as you possibly can in supplying data which will aid in settling the questions which the Committee is considering, and the Committee, I know, will highly appreciate it.

The President:—The convention wishes to thank this Committee. They have been working in an unknown field, and I know they did not receive proper information, as stated previously by the Chair. They have now stated the matter in such way that we know what they want; and it is the duty of the different railroads represented here to furnish to the Committee the information in the best way they can. We also wish to thank Mr. Begien and the officials of the Baltimore & Ohio Railroad for the valuable information that has been furnished by that railroad.

Mr. W. J. Wilgus (Consulting Engineer, by letter):—I have been much interested in reading the report of the Committee on Economics of Railway Location, especially the part bearing on the suggested method of segregating certain items of maintenance expenditures between passenger and freight service.

It would seem that this point has a vital bearing not alone on economics of railway location, but also on another matter that is at least equally important.

The ascertainment of reasonably accurate costs of transporting passengers and freight is becoming increasingly necessary as a basis for resisting improper rate reductions, and for securing higher rates where their fairness can be proven.

While a few of the I. C. C. classification items of maintenance fluctuate in proportion to train mileage handled, the majority of them are, as stated by the Committee, directly or indirectly affected by the gross weight ton mileage that rolls over the rails. The question then arises—should the actual tonnage be taken, embracing locomotives, cars and contents, or should an attempt be made, as recommended by the Committee, to make allowance through "equivalent ton mileage" for excess damage assumed to be done to track and structures by the higher speed passenger trains and by locomotives as compared with the load they haul?

As regards the comparative effect of passenger and freight trains, it is the opinion of the writer that, generally speaking, there is no appreciable difference, if in considering the higher speeds in passenger service equal attention is paid to destructive agencies peculiar to the freight service, such as drippings from coal and refrigerator cars, imperfections of equipment, heavier wheel concentrations, twisting action of locomotives at slow speeds, littering of roadbed and the fouling and destructive action of the products of combustion of inferior grades of coal used in freight service.

Corrosive drippings are detrimental to floor beams and stringers and solid floors of bridges; to track fastenings such as spikes, tie-plates, bolts and splices; and to rails, frogs and switches.

Side bearings on freight cars are so stiff as to provide much less freedom of adjustment to varying track conditions than on passenger cars. This has been strikingly shown on tracks used exclusively for freight traffic, where trucks in passing from curve to tangent retain their slewed position and grind the outer rail for considerable distances.

Springs under freight cars are less delicately adjusted than on passenger cars, with correspondingly greater shock to track and structures, especially in the case of eight-wheel coal cars having 18,750 lbs. per wheel as contrasted with 12-wheel passenger coaches weighing but 12,500 lbs. per wheel.

Superworn tires, flat spots on wheels, dragging brake beams and draft rigging, and similar imperfections peculiar to freight equipment, cause additional wear and tear.

Slowly moving freight locomotives when exerting their maximum tractive force, cause a twisting action from side to side that tends to work track out of line as much or more than higher speed passenger trains.

Droppings from freight trains such as lumps of coal, rubbish, loose doors and other broken parts, increase danger and add to the cost of policing.

Freight locomotives consume more coal and use a poorer grade of fuel, and the resulting larger volume of cinders, gases and smoke fouls

the ballast, corrodes metallic structures, and injures paint on buildings, bridges and signals to a greater extent than with passenger power.

Freight locomotives under load stop and start more frequently, causing slipping of drivers that blisters and wears the rail.

Local freights do more or less switching on main tracks and at stations, with accompanying wear and tear on track and structures.

On many railroads both "drag" and preferential freight trains on certain divisions, in order not to interefere with the passenger service, are run at high speeds, and any fixed rule for calculating "equivalent ton mileage" would have to be varied to meet these frequent conditions.

It therefore seems clear that relative speeds of passenger and freight trains are so variable and the instances in which the latter are more destructive to track and structure so numerous, that any attempt to arbitrarily fix the percentage that one exceeds the other would lead to questionable results. Judgment, which in any event must guide a decision, would seem to lead to the conclusion that, taking all these facts into consideration, the added cost of maintenance chargeable to passenger service by reason of higher speeds is practically offset by many features incident to the slower speed traffic.

As to the comparative effect of locomotives and of the load they haul, it is possibly true that the former cause somewhat more damage per ton than the latter, but not to the extent that might be imagined. For instance, taking two loaded coal cars weighing 150 tons, their smaller diameter wheels, less perfect construction and maintenance, and drippings and droppings, may be said to go far toward equalling the twisting and corrosive effects of a locomotive of the same weight; and in passenger service the smaller wheels and tail-end side swing may be considered as going far toward equaling the destructive action of the locomotive.

To guess that the locomotive, including its tender, creates twice as much destructive action per ton of gross weight as the load it hauls, may yield a result more in excess of the truth than the making of no allowance may understate the truth.

Summarizing, in the absence of precise data, and taking into account the complexity of the problem, is it not fair to say that under *average conditions* a gross weight ton of passenger train creates the same destructive effect on track and structures as a gross weight ton of freight train; and that an attempt to assign constructive tonnage to portions of the rolling load as the measure of their assumed excess wear and tear on track and structures, will result either in complications and contradictions, or in so many variations in the formula as to make the exceptions prove the rule.

DISCUSSION ON WOODEN BRIDGES AND TRESTLES.

(For Report, see pp. 652-697.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WOODEN BRIDGES AND TRESTLES.

GEO. W. ANDREWS.	J. B. JENKINS.	L. S. ROSE.
W. M. CAMP.	C. E. LINDSAY.	R. C. SATTLEY.
J. L. CAMPBELL.	C. F. LOWETH.	I. L. SIMMONS.
F. J. BACHELDER.	H. T. PORTER.	C. E. SMITH.

The President:—The report of the Committee on Wooden Bridges and Trestles will be presented by the Chairman, Mr. I. L. Simmons.

Mr. I. L. Simmons (Chicago, Rock Island & Pacific):—The report of the Committee is given on pp. 652-697 of Bulletin 153, and I would suggest that we take up first the conclusion of the Committee regarding guard-rails.

The Secretary:—"(1) It is recommended as good practice to use guard timbers on all open-floor bridges, and same should be so constructed as to properly space the ties and hold them securely in their places."

Mr. I. L. Simmons:—I move that conclusion 1 be adopted as good practice.

Mr. J. L. Campbell (El Paso Southwestern):—I ask if this report is intended to cover the wooden guard-rail outside of the track rail only?

Mr. I. L. Simmons:—This is for the guard-timber, and the guard-timber is considered as the guard-rail on the outside of the bridge.

(Conclusion 1 was adopted.)

The Secretary:—"(2) It is recommended as good practice to use guard-rails on open deck ballasted structures over 35 ft., the guard-rails to extend beyond the ends of the bridges for such a distance as required by local conditions, but that this length in any case be not less than 50 ft.; that guard-rails be fully spiked to every tie and spliced at every joint, the guard-rail to be some form of a metal guard-rail."

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—Is it the recommendation to have guard-rails on all bridges?

Mr. I. L. Simmons:—Yes.

Mr. Rose:—I think that is going a little too far. Extending that reasoning a little, you will want a guard-rail on every fill, and you will have a railroad with a guard-rail from one end to the other.

Mr. C. E. Lindsay (New York Central & Hudson River):—I suggested to the Committee, after the last meeting, the use of a different term to designate the rail that was placed between the running rails to guide derailed wheels, to distinguish it from the "guard-rail," as we

ordinarily understand the term applied to a device at frogs and switches, and other openings in the gage line, and the Committee saw fit to reject my suggestion. I believe the subject is inconsistent as it now stands. I suggested the use of the words "guide-rail" for this inner rail. Its purpose is to guide derailing wheels past the point of danger. When you look in the Manual for a definition of "guard-rail" you will find it is "a longitudinal member, usually a metal rail secured on top of the ties inside the track rail to *guide derailed wheels.*" Our understanding of guard-rail is that it is a device *to prevent wheels from being derailed,* and I think there should be a definite term for this inner rail, so that the terms "guard-timber" and "guard-rail" will not be used indiscriminately and improperly.

I have taken some definitions from the Manual, which I will read:

"Guard-Rail.—A longitudinal member, usually a metal rail, secured on top of the ties inside of the track rail, to guide derailed car wheels.

"Guard-Timber.—A longitudinal timber framed over the ties outside of the track rail, to maintain the spacing of the ties."

On the question of the advisability of using guide-rails at all bridges, I am certainly opposed to that. The use of a guide-rail is to minimize the effect of a derailment in that particular locality. I think that the Dominion of Canada has done a very sensible thing in confining the use of guide-rails to openings more than 50 ft., but I think it is necessary to go further. The object of the guide-rail is to minimize the effect of derailments at points—where there is a structure which might be damaged by the derailed car, or where the curvature is excessive, or the speed great, or where the height of an opening into which a vehicle might fall would be so great as to make a terrible calamity, or where the clearances are close and the speed excessive.

There is no sense in putting in a guide-rail where there are turnouts close by. That would not minimize the result of derailment. Take a slow-speed point where a derailed wheel would do no great harm, a guide-rail is of no use and I hope the Committee will reconsider this action and seriously consider a definition of the term "guide-rail," and limit its use.

Mr. C. F. Loweth (Chicago, Milwaukee & St. Paul):—Mr. Lindsay has said what I had in mind. I am opposed to any recommendation that we should put guide-rails or guard-rails, whatever they may be termed, on all bridges. It is an unnecessary expense, and is not in accordance with the facts or practice as indicated in the tabulation of the statement of the various roads in the Committee's report.

Mr. J. L. Campbell:—I agree with Mr. Loweth and Mr. Lindsay about the requirement for guard-rails on all bridges. Many bridges are only 14 ft. long. Referring to page 664, I think the Committee has shown what it intended to say in the recommendation. We there have Mr. Lindsay's definition of guard-rail on the outside and guide-rail on the inside. I raise a question about the necessity—in fact, I am of the opinion that the guard-rail on the outside of and beyond the end of bridge is a

source of danger. I think that any guard-rail outside of the track rail has a tendency to aggravate the position of the derailed truck and to slew it across the track. I believe the guard-rail at the end of the bridge should be removed and that we should depend entirely on the guide-rails instead of the track rails.

My suggestion is to refer this section of the report back to the Committee to give the matter further study and bring in a definition of the guide-rail and guard-rail that we are talking about.

Mr. F. J. Bachelder (Baltimore & Ohio) :—Do we not define the guard-rail when we speak of it in connection with the bridge? We speak of the inner guard-rail of the bridge always in connection with the bridge, and the outer guard-rail of the bridge always in connection with the bridge. Does not that define it properly?

Mr. R. C. Sattley (Chicago, Rock Island & Pacific) :—As Superintendent of Bridges and Buildings for some eleven years on a railroad, it is my opinion that it is necessary to protect truss bridges with an inner guard-rail, and we always advocate the putting of the inner guard-rail 150 ft. from the end of the bridge. We have always followed this practice.

Mr. W. M. Camp (Railway and Engineering Review) :—There is much confusion in the double use of the term "guard-rail," to indicate the rail which is intended to protect the point of a frog or to prevent derailment on a sharp curve, in one case, and the use of the same term to indicate the rails that are intended to guide trucks that may be derailed on a bridge. In some specifications which I have seen the device to be used on a bridge was in every case clearly indicated by terming it a "bridge guard-rail." The English avoid this difficulty by calling the guard-rail used opposite the point of a frog a "check-rail." Our term "guard-rail" for turnouts is in such common usage that there would hardly be any disposition to change it for that purpose. As I have just suggested, one way to indicate exactly what is meant would be to prefix the word "bridge" in every case where the guard-rail was to be used on a bridge.

Mr. C. E. Smith (Missouri Pacific) :—The Missouri Pacific Railway has about 800,000 linear feet of bridges; about 10,000 bridges. If guard-rails were put across these bridges, including 50 ft. beyond each end of each bridge, there would be about 1,800,000 ft. of track to protect, which, at 75 cents per linear foot, would cost $1,350,000, the interest on which, at 6 per cent., would amount to about $80,000 a year increased charges to the Railway Company for so protecting the bridges. There have been some derailments that have caused wrecks on bridges and trestles on this railroad, but I do not know of a case where any guard-rail would have prevented such wrecks. Even if the inner guard-rails had been there, and had eliminated the wrecks, the saving to the railway would not have equaled the increased interest charge, and the Company would still be away behind on the investment. Guard-rails may be good from a sentimental standpoint, they may be justified on some roads which have a

small mileage of bridges, or heavy traffic, but the great majority of roads cannot afford to use them according to the recommendations of the Committee.

Mr. I. L. Simmons:—I do not see that the recommendations carry the same effect that a State law would. It is not a question whether a railroad can afford to do it or not, but a question whether the damage to the structures in the past has warranted putting them on. There is another feature in this matter which must be taken into consideration, and that is the public. You have to consider them sooner or later. It is not a question whether we can afford to do it or not. We had that in mind.

So far as the short length of bridge is concerned, you can have as disastrous a wreck on a 15-ft. bridge as on a 500-ft. bridge. The length does not make any difference; the location might make some. That is to be determined by the man who has the matter in charge.

These questions were threshed out in Committee and we will have to be guided by the consensus of opinion of the Association, but I believe the report would cover the case, and you would leave sufficient latitude to enable you to decide upon which bridges you would want the guard-rails.

Mr. Lindsay:—I am in accord with the last speaker. In the last analysis the public "pays the freight." I will remind you that the public authorities are largely guided by what this body says and what it prints in its Manual and its Proceedings. I hope, therefore, that the Committee will get together, with the Track Committee, and give us a definition for a "guard-rail," as ordinarily understood, and a "guide-rail," and give us the greatest latitude for the exercise of judgment and good sense in the use of devices for the protection of human life.

Mr. Rose:—I think the question of guide-rails is pretty largely a matter of sentiment. I have known of some derailments where there was a guide-rail and it had no effect; the outer timber did the work. I hope this convention will not rule that guide-rails are necessary. I do not believe they are necessary, judged by the amount of good they serve.

Mr. G. W. Andrews (Baltimore & Ohio):—I take exception to what Mr. Rose has said. I know from practical experience that the inner guard-rail is of decided benefit. We have had a number of derailments, and if it had not been for the inner guard-rail the engine and possibly a large number of cars would have gone down the embankment. We have installed inner guard-rails upon a great number of our bridges, especially those on high-speed track, and I believe the resultant effect is beneficial. I know how difficult it is to get away from fixed ideas. We all have our opinions as to what is best, regardless of what the other man may think, but I believe in this particular case the Committee has made a very excellent suggestion.

Mr. R. C. Sattley:—I would like to ask Mr. Andrews if he will please tell the convention the distance that he uses from the center rail to the end of the guide or guard-rail?

Mr. G. W. Andrews:—Our standard requirement shows 150 ft., but that has been reduced in a number of cases to less than 100 ft.

Mr. Loweth:—I believe we are apt to be confused on the issue involved here. As I understand it, the Committee proposes that there should be what is known as inside guard or inside guide, and those rails, whatever they may be, must be on all bridges. Now, it is to that expression of the Committee that these guards or guides should be on all bridges that I take exception. I am just as firm a believer in the need and the economy of inside guard-rails on bridges as anyone else can be, and I have had experience which fully justifies the cost on some bridges, but not on all. There are a great many bridges in which there is no great need for protection of that kind. If it is necessary to put in protection of that kind on short, shallow bridges, why do we not put it in over the miles of high embankment that we have, where the consequences of derailment would be much more serious than would be the case in many shallow bridges? I think that we ought to refer this back to the Committee, with instructions that they should not return a recommendation for inside guard-rails on all bridges.

The President:—The amendment before us is that conclusion No. 2 be referred back to the Committee, with the understanding that they will first give a clear definition of what "inside guard-rail" is, whether we call it "inside guard" or "guide-rail," and if the sense of the discussion is to be followed, then, finally, whether or not this conclusion shall apply to all bridges, which the Committee state now is the intention of the conclusion.

Mr. Rose:—I would like to amend the motion by adding to it that the Committee shall bring in no recommendation as to where guide-rails shall be placed. I believe it is all right for the Committee to show how guide-rails shall be put in, if we are going to use them, but I do not think the Committee should make any recommendation as to where they should be used.

The President:—The Chair hardly thinks that is within the province of the Association.

Mr. H. T. Porter (Bessemer & Lake Erie):—I would like to second Mr. Rose's amendment, and I would like to say in support of that contention that the inside guard-rail is for the purpose of guiding a derailed wheel. When the cars were 60,000 lbs. capacity, by putting in guard-rails carefully, we did have some confidence in their being able to guide a derailed wheel, but since we have reached an axleload on cars of from 35,000 to 40,000 lbs. the condition has changed. We have had cases where a derailed truck on an ore car has followed the track over three miles and missed but very few spikes and bolts. We have had other cases where the derailed car crossed the track and went down the bank in less than 60 ft. We have had cases where the car tore out a guard-rail that was thoroughly spiked, and when the matter was under investigation I told our people that I believed that a black stripe painted along the ties would have done as much good as the guard-rail. When

your wheel is derailed and comes up against the guard-rail, the situation is different from having the weight of the wheel on the rail. Any fastenings that I have been able to use, have proved insignificant, when they would have to resist the pressure of a derailed truck, where the load on the axle is 35,000 to 40,000 lbs., and where the truck has a tendency to cross the track. So I feel that this convention should in no way commit itself to the proposition that a guard-rail will accomplish the purpose for which it is put in. It might be all right if we would go far enough to say that it will do no harm, and in some cases might do good.

Mr. G. W. Andrews:—I would like to ask Mr. Porter what kind of ties he has in his track on the approaches to the bridge? He remarked that he had been unable to get fastenings that would hold in case of derailment, and for that reason I desire to ask him what kind of ties he uses on his track.

Mr. H. T. Porter:—Well, of course, at the time we had this trouble we were using yellow pine ties on our bridges and West Virginia white oak ties in our track, and used a frog point at the place where the two guard-rails met.

Mr. G. W. Andrews:—Did you use the wooden tie or steel tie in all cases? Have you not used a number of steel ties in your track?

Mr. H. T. Porter:—Yes, sir, we have about 800,000 steel ties in our track.

Mr. G. W. Andrews:—I thought possibly you had steel ties in your bridges, which made it impossible to get proper fastenings. We have had some experience somewhat the same as you have had. In every case where we had derailments of the ties such as you used, the fastenings were destroyed.

Mr. Lindsay:—I am entirely in sympathy with Mr. Rose's amendment, yet I cannot endorse the probable action of the Committee, in requiring guide-rails on all bridges. I think we have given too little attention to the consideration of this subject in connection with the theory of probabilities, and I think as experts on the subject we ought to give greater thought to it. The guide-rail, where it is brought to the frog point, introduces two elements of danger which must be guarded against. One is the possibility of chains or other parts of equipment catching in the frog point and tearing off and *causing derailment*. Another is the possibility of employes getting their feet caught between the guide-rail and the main running rail, either at the frog point or at intermediate points and injury resulting. So those elements ought to be taken into consideration. I believe in guide-rails, I believe there are points where they should be used, but we should be given the greatest latitude in using them. I think it would be advisable also to use a rerailing device in connection with them.

The President:—We are getting off of the subject a little. The Chair mentioned a moment ago that the motion of Mr. Rose was hardly in order in view of the motion before us, to refer this back to the Committee.

The Chair allowed discussion to go on simply to get information. There are a great number of railroads using inside guard-rails. They are used very extensively in this country. It is the province of this Association to give good practice; where they shall be used and how they shall be used, and the Committee ought not to be limited in their recommendations that they are to make hereafter. We have before us the question, shall this conclusion No. 2 be referred back to the Committee?

(Upon vote, the motion was carried.)

The President:—No. 2 being referred back to the Committee, the Secretary will read No. 3.

The Secretary:—"(3) It is recommended that the guard-timber and guard-rail be so spaced, with reference to the track rail that a derailed truck will strike the guard-rail without striking the guard-timber."

Mr. Lindsay:—I do not object to the conclusion, but I would like to ask whether a definition ought to be adopted.

Mr. I. L. Simmons:—It seems to me the question of what shall be adopted, whether you mean the inner rail or the outer rail, is entirely covered by the definition of "guard-rail" in the Manual. That states distinctly that it is an inner rail. I cannot see how there can be any confusion on that term as used.

The President:—The Committee has already inserted the word "inside" in the previous discussion. It is presumed you wish to have No. 3 read.

Mr. I. L. Simmons:—"The guard-timber and the inner guard-rail *shall* be so spaced in reference to the track rail that the rear truck will strike the inner guard-rail without striking the guard-timber."

The President:—That would be the wording if the previous recommendation was adopted by the Committee.

Mr. Loweth:—I would like to suggest that the Committee add, after the words "guard-rail," in the first line, "when used," so that it will read, "It is recommended that the guard-timber or guard-rail, when used, be so spaced."

The President:—The Committee accepts that.

The Secretary:—"(4) The height of the guard-rail to be not over one inch less than the running rail."

Mr. I. L. Simmons:—"Inner guard-rail" to be inserted. I move that this be adopted as good practice.

Mr. J. B. Jenkins (Baltimore & Ohio):—I move to amend that by inserting "inside guard-rail must not be higher or over one inch lower than the running rail."

The President:—The Committee accepts that. As it now stands it reads, "The height of the inner guard-rail shall be not higher than nor more than one inch less than the running rail."

Mr. Jenkins:—"The inside guard-rail must not be higher or over one inch lower than the running rail."

The President:—That has been accepted by the Committee. The Chair will put that motion.

(Conclusion 4 was adopted as amended.)

The President:—The remainder of the Committee's report is in the nature of information, and valuable information as far as the inside guard-rail is concerned and much other matter. The Committee is excused, with the thanks of the convention.

DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS.

(For Report, see pp. 699-709.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS.

W. G. Atwood.
Geo. H. Bremner.
G. D. Brooke.
W. M. Camp.
J. L. Campbell.
Robert Ferriday.
L. C. Fritch.
Geo. E. Gifford.
Edward Gray, Jr.
V. K. Hendricks.
C. P. Howard.
Geo. W. Kittredge.
H. A. Lloyd.
Hunter McDonald.
F. P. Patenall.
S. S. Roberts.
L. S. Rose.
R. A. Rutledge.
Edwin F. Wendt.
C. A. Wilson.

The President:—The report of the Special Committee on Uniform General Contract Forms will be presented by the Chairman, Mr. W. G. Atwood.

Mr. W. G. Atwood (Lake Erie & Western):—The statement of the Committee, on pp. 699 and 700, covers about everything that they have to say. I might say, however, that in the matter of referring the contract to the legal departments of railroads, comparatively a great many of them made considerable study and the criticisms, of which there were twenty-five, more or less extended, some of them quite long, and except for the lien clause they did not affect the general subject-matter of the contract, except in some cases. Thirty-five legal departments approved the form as it stands, except for the lien clause. That lien clause we changed as a result of their criticism.

Mr. L. C. Fritch (Chicago Great Western):—I think this Committee has given us a very excellent form of contract. They requested that various members criticise the report, and I sent it to our legal department and they commented very favorably on it, and saw no objections to it from a legal standpoint. It seems to me that if we can agree on this form of contract and adopt it as widely as possible, it will certainly be of great benefit to us. It will mean that contractors doing work for the various companies will do so under uniform conditions. With very few minor changes, this contract seems acceptable, as far as we are concerned. I think it is important enough to have the whole contract read paragraph by paragraph.

The President:—Unless there is objection, we will follow this course, the Secretary reading the paragraphs, just pausing a moment before going on, after each paragraph.

The Secretary:—"Construction Contract. "A" Agreement.—This agreement, made this.....day of.....in the year..... by and between.....party of the first part, hereinafter called

the Contractor, and.....party of the second part, hereinafter called the Company.

"Witnesseth, That, in consideration of the covenants and agreements hereinafter mentioned, to be performed by the parties hereto, and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

"The Contractor shall furnish all the necessary transportation, except as hereinafter specified, materials, superintendence, labor and equipment, and shall execute, construct and finish, in an expeditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer of the Company..... in accordance with the plans hereto attached, identified by the signatures of the parties hereto, or herein described, and the following general conditions, requirements and specifications, forming part of this contract.

"The work covered by this contract shall be commenced..... .....and be completed on or before the .....day of.....191...., time being of the essence of this contract.....

"And in consideration of the completion of the work described herein, and the fulfillment of all stipulations of this agreement to the satisfaction and acceptance of the Chief Engineer of the Company, the said Company shall pay, or cause to be paid, to said Contractor, the amount due the Contractor, based on the following prices:

"This agreement shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

"In Witness Whereof, The parties hereto have executed this agreement in.....the day and year first above written."

Mr. L. C. Fritch:—I would like to suggest that the Company be placed first. It is usual to have the Railroad Company made the party of the first part.

Mr. W. G. Atwood:—This form, which we have named "A," for convenience, was approved by the convention last year. Of course it is open to amendment, if you wish to take it up. But the Committee recommends two minor amendments to it. I think it will require a motion probably to take up the matter of changing this form as it stands, because, as I remember the action of the convention last year, form "A" was accepted.

The President:—Will the Committee accept the change as suggested by Mr. Fritch?

Mr. W. G. Atwood:—The Committee is not prepared to accept that change. Their reason for placing the contractor first was because the contractor signs the contract first; his name appears, and it did not seem material to us, except as a matter of harmony, which did occur first as party of the first part.

Mr. V. K. Hendricks (St. Louis & San Francisco):—I would like to ask, as a matter of information, how the blank space after "time being of the essence of this contract" is to be filled in. Is it supposed to fill in different times for different parts of the work?

Mr. W. G. Atwood:—That is for qualification or specification and description that will fit in the different cases, and the blank is left to be used for any of those purposes.

Mr. H. A. Lloyd (Erie):—It says, "all necessary transportation, except as hereinafter specified." Should that not be after labor and material, and refer to labor and material as well as transportation?

Mr. W. G. Atwood:—It is the practice of many roads to furnish transportation for both labor and material; it is the practice of others not to furnish it. It was the intent of the Committee to so draw this clause that without an additional clause, which each company can insert to cover their own conditions and wishes, transportation will not be furnished by the Company; the contractor will furnish his own transportation, except that a clause be inserted specifying just what the Company will furnish.

Mr. Lloyd:—The labor and material, as I understand it, in all contracts, is subject to the Company furnishing part of it, and the contractor the rest. The proposed contract would indicate that it is only the intention of the Company to furnish part of the transportation. Should we not understand that they are going to furnish part of the materials, too?

Mr. L. C. Fritch:—The same thought struck me, when I read this contract. I believe it would be an improvement if "all the necessary transportation, except as hereinafter specified," would follow after equipment. Then it would be sure to cover everything—labor, material and equipment.

Mr. W. G. Atwood:—The Committee will accept that change.

Mr. W. M. Camp (Railway and Engineering Review):—Will the Chairman read that as it is revised?

Mr. W. G. Atwood:—"The contractor shall furnish all material, superintendence, labor, equipment and transportation, except as hereinafter specified."

The Secretary:—"Construction Contract. "B" General Conditions.—Bond. 1. The Contractor agrees, at the time of the execution and delivery of this contract and before the taking effect of the same, to furnish and deliver to the Company a good and sufficient bond of indemnity to the amount of.....dollars, as security for the faithful performance, by the Contractor, of all the covenants and agreements on the part of the Contractor contained in this contract. The security in such bond of indemnity must be satisfactory and acceptable to the Company.

"This bond shall remain in force and effect in such amount, not greater than that specified, as shall be determined by the Chief Engineer, until the final completion and acceptance of the work.

"Contractor's Understanding. 2. It is understood and agreed that the Contractor has, by careful examination, satisfied himself as to the nature and location of the work, the conformation of the ground, the character, quality and quantity of the materials to be encountered, the character of equipment and facilities needed preliminary to and during the prosecution of the work, the general and local conditions, and all

other matters which can in any way affect the work under this contract. No verbal agreement or conversation with any officer, agent or employe of the Company, either before or after the execution of this contract, shall affect or modify any of the terms or obligations herein contained.

"Intent of Plans and Specifications. 3. All work that may be called for in the specifications and not shown on the plans, or shown on the plans and not called for in the specifications, shall be executed and furnished by the Contractor as if described in both these ways; and should any work or material be required which is not denoted in the specifications or plans, either directly or indirectly, but which is nevertheless necessary for the proper carrying out of the intent thereof, the Contractor is to understand the same to be implied and required and shall perform all such work and furnish any such material as fully as if they were particularly delineated or described."

Mr. Geo. E. Gifford (Bridge Builders' Society):—Mr. Chairman, I take exception to paragraph 3, in so far as it applies to indefiniteness of plans. It seems to me that the contractor should be furnished with complete information by the Engineer, and that it is much easier for the Engineer who prepares the plans and specifications to say what he wants than it is for the contractor to guess in advance what may be required. I imagine that every contractor—and I have been following this line of work as a Contracting Engineer all my professional life—has found a great many hardships at various times, on account of loose construction of a specification of this kind. I remember, on one occasion, where my concern had a contract for a tin roof on a very large manufacturing plant; the specifications stated explicitly that the *underside* of the tin had to be painted before it was laid. There was not a word said about painting the tin roof after it was finished. Naturally it was thought the Engineer knew what he was about, and that for some reason he did not want the roof painted; at any rate the specifications said nothing about painting the roof. When it came to finishing up I was informed the roof had to be painted. The Engineer said, "I cannot call this a finished job until you paint that roof." We, thereupon, went to work and painted the roof at an expense of several hundred dollars. The question was made the subject of an extra claim and we were reimbursed. That shows what unfair construction can be given to a loose clause of this kind, and it seems unjust for the contractor to be required to guess on what may be demanded.

I move that, beginning in the middle of the fourth line, "and should any work or material," etc., to the end of the paragraph, all be stricken out.

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—I hope that motion will not prevail. I think it would leave the question open for contractors to leave off some part of their work and then claim that the specifications did not cover it, whereas the work is generally performed. I think if painting a roof is a general proposition, they should figure on painting the roof.

Mr. L. C. Fritch:—I agree with what Mr. Rose has said. We should allow this to stand as it is for the reason that if you put the burden on the Company, it will be necessary to specify every small minor detail. We all know that in carrying out work some things are overlooked, and if they are a part of the complete job that work should be done, whether it is shown in the plans and specifications or not. If there are any unusual conditions, something that is not the intent of the contract, the contractor has the right to object to it, and I think any fair-minded Engineer would allow him to be paid for it.

(Motion lost.)

The Secretary:—"Permits. 4. Permits of a temporary nature necessary for the prosecution of the work shall be secured by the Contractor. Permits for permanent structures or permanent changes in existing facilities shall be secured by the Company."

Mr. Rose:—I do not quite understand that permit arrangement. I think in many cases it would be better for the Company to get the permit than the contractor. This is a general contract and covers the erection of buildings or the installation of machinery. The question of putting up power wires might be involved. You make the contractor get the building permit from the city under this clause, and I do not believe that is just right.

Mr. L. C. Fritch:—This refers simply to temporary permits. Any permanent permit should be secured by the Company.

Mr. W. G. Atwood:—In a case, for instance, where a contractor is erecting a building, if he needs a permit to put up a derrick, he should get it himself. If power wires are to be strung permanently, if they are part of the installation, the permits should be obtained by the Company. Anything which the contractor has to do which is temporary, for the purpose of carrying out the work, that is for his own benefit, the contractor should secure the authority to do. If there is any permanent change, another railroad or a public facility of any kind, the Company certainly should secure the permit.

The Secretary:—"Protection. 5. Whenever the local conditions, laws or ordinances require, the Contractor shall furnish and maintain, at his own cost and expense, necessary passageways, guard fences and lights and such other facilities and means of protection as may be required.

"Rights of Various Interests. 6. Wherever work being done by Company forces or by other Contractors is contiguous to work covered by this contract, the respective rights of the various interests involved shall be established by the Engineer, to secure the completion of the various portions of the work in general harmony.

"Consent to Transfer. 7. The Contractor shall not let or transfer this contract or any part thereof (except for the delivery of material) without consent of the Chief Engineer, given in writing. Such consent does not release or relieve the Contractor from any of his obligations and liabilities under the contract.

"Superintendence. 8. The Contractor shall constantly superintend all the work embraced in this contract, in person or by a duly authorized manager acceptable to the Company.

"Timely Demand for Points and Instructions. 9. The Contractor shall not proceed until he has made timely demand upon the Engineer for, and has received from him, such points and instructions as may be necessary as the work progresses. The work shall be done in strict conformity with such points and instructions.

"Report Errors and Discrepancies. 10. If the Contractor, in the course of the work, finds any discrepancy between the plans and the physical conditions of the locality, or any errors in plans or in the layout as given by said points and instructions, it shall be his duty to immediately inform the Engineer in writing and the Engineer shall promptly verify the same. Any work done after such discovery, until authorized, will be done at the Contractor's risk.

"Preservation of Stakes. 11. The Contractor must carefully preserve bench marks, reference points and stakes, and in case of wilful or careless destruction, he will be charged with the resulting expense, and shall be responsible for any mistakes that may be caused by their unnecessary loss or disturbance.

"Inspection. 12. All work and materials shall be at all times open to the inspection, acceptance or rejection of the Engineer or his duly authorized representative. The Contractor shall provide reasonable and necessary facilities for such inspection.

"Defective Work or Material. 13. Any omission or failure on the part of the Engineer to disapprove or reject any work or material shall not be construed to be an acceptance of any defective work or material. The Contractor shall remove, at his own expense, any work or material condemned by the Engineer, and shall rebuild and replace the same without extra charge, and in default thereof the same may be done by the Company at the Contractor's expense, or, in case the Chief Engineer should not consider the defect of sufficient importance to require the Contractor to rebuild or replace any imperfect work or material, he shall have power, and is hereby authorized, to make an equitable deduction from the stipulated price.

"Insurance. 14. The Contractor shall secure in the name of the Company and for its benefit policies of fire insurance on such structures, and in such amounts as shall be specified by the Chief Engineer not exceeding....."

Mr. Rose:—I would like to ask the Committee a question about insurance. I would like to know if it is possible to carry out this section 14, taking out insurance in the name of the Company for property the Company does not own—has not yet accepted.

Mr. L. C. Fritch:—It is usual to add, after the word "Company," "as its interest may appear." That covers the point.

Mr. Rose:—I think it would be necessary to assign that portion of the work that is covered by insurance to the Company in order to collect the insurance. The case I have in mind is the installation of some special machinery in a building, and the insurance covering that part of the machinery that is installed is to be made out to the Company, but to cover that, that special machinery must be assigned from time to time to the Company, in order that the Company can collect the insurance if there is a fire, but the Company should not collect the insurance on property it does not own.

Mr. W. G. Atwood:—It is the opinion of the Committee that structures erected or material furnished to the Company on the right-of-way under this contract, which provides for certain definite payments, is the Company's property, when it is so erected and furnished; and that the contractor has a lien on it, but the material or structure is the property of the Company.

Mr. Gifford:—The matter of insurance is one that can be readily taken care of by the Company itself. Builder's risks can very readily be taken care of. In my opinion the paragraph is correct as it stands.

The Secretary:—"Indemnity. 15. The Contractor shall indemnify and save harmless the Company from and against all claims, demands, payments, suits, actions, recoveries and judgments of every nature and description brought or recovered against it, by reason of any act or omission of the said Contractor, his agents or employes, in the execution of the work by or in consequence of any negligence or carelessness in guarding the same.

"Settlement for Wages. 16. Whenever, in the opinion of the Chief Engineer, it may be necessary for the progress of the work to secure to any of the employes of the Conractor any wages which may then be due them, the Company is hereby authorized to pay said employes the amount due them or any lesser amount, and the amount so paid them, as shown by their receipts, shall be deducted from any moneys that may be or become payable to said Contractor.

"Liens. 17. If at any time there shall be evidence of any lien or claim for which the Company might become liable and which is chargeable to the Contractor, the Company shall have the right to retain out of any payment then due or thereafter to become due, an amount sufficient to completely indemnify the Company against such lien or claim, and if such lien or claim be valid, the Company may pay and discharge the same, and deduct the amount so paid from any moneys which may be or become due and payable to the Contractor.

"Work Adjacent to Railroad. 18. Whenever the work embraced in this contract is near the tracks, structures or buildings of this Company or of other railroads, the Contractor shall use proper care and vigilance to avoid injury to persons or property. The work must be so conducted as not to interfere with the movement of trains or other operations of the railroad; or, if in any case such interference be necessary, the Contractor shall not proceed until he has first obtained specific

authority and directions therefor from the proper designated officer of the Company and has the approval of the Engineer.

"Risk. 19. The work in every respect shall be at the risk of the Contractor until finished and accepted, except damage or injury caused directly by Company's agents or employes."

Mr. Rose:—I would like to ask the Committee if it is the intention that the contractor shall take the risk of the annulment of the contract by agencies that neither the contractor nor the Company can control? As an example, a contract might be made for some special interlocking machinery, and the interlocking building going down before the contractor installs this special machinery; or another case I have in mind is the installation of a number of electric motors in a grain elevator. Part of these motors are special machines. A case might come up where the elevator might burn down, and for good and sufficient reasons it would be inadvisable to rebuild it. The contractor has on his hands a number of special machines that he cannot dispose of, and if he is to take all the risk, will he have to sustain that loss?

Mr. W. G. Atwood:—In the special case brought up by Mr. Rose, we think that the annulment clause would cover that and that this clause on risk does not refer to cases of that kind. In these special cases it would be a whole or partial annulment of the contract and would not be a risk assumed by the contractor.

Mr. Rose:—I appreciate that the two clauses are tied together, but you have said that the contractor will take the risk until the work is accepted. He might do it all right and take out some kind of insurance to cover that—we pay for it, though.

Mr. W. G. Atwood:—We think that is covered in the contract as it exists until annulled.

The Secretary:—"Order and Discipline. 20. The Contractor shall at all times enforce strict discipline and good order among his employés, and any employé of the Contractor who shall appear to be incompetent, disorderly or intemperate, or in any other way disqualified for or unfaithful to the work entrusted to him, shall be discharged immediately on the request of the Engineer, and he shall not again be employed on the work without the Engineer's written consent.

"Contractor Not to Hire Company's Employés. 21. The Contractor shall not employ or hire any of the Company's employés without the permission of the Engineer.

"Intoxicating Liquors Prohibited. 22. The Contractor, in so far as his authority extends, shall not permit the sale, distribution or use of any intoxicating liquors upon or adjacent to the work, or allow any such to be brought upon, to or near the line of the railway of the Company.

"Cleaning Up. 23. The Contractor shall, as directed by the Engineer, remove from the Company's property and from all public and private property, at his own expense, all temporary structures, rubbish and waste materials resulting from his operations.

"Engineer and Chief Engineer Defined. 24. Wherever, in this contract, the word Engineer is used, it shall be understood as referring to the Chief Engineer of the Company, acting personally, or through an assistant, duly authorized, in writing, for such act by the Chief Engineer, and wherever the words Chief Engineer are used it shall be understood as referring to the Chief Engineer in person and not to any assistant engineer."

Mr. Hendricks:—I would like to ask the Committee if they would not like to recommend placing that at the beginning of the contract? In other words, place the definition before the use of the term.

Mr. W. G. Atwood:—The Committee has endeavored to arrange the clauses in the contract in the same order as they have drawn the agreement form; that is, all the duties and acts of the Contractor first, as his name appears first, as party of the first part, and the definitions and duties of the Company last. That is the reason for that clause being there.

The Secretary:—"Power of Engineer. 25. The Engineer shall have power to reject or condemn all work or material which does not conform to this contract; to direct the application of forces to any portion of the work which, in his judgment, requires it; to order the force increased or diminished, and to decide questions which arise between the parties relative to the execution of the work.

"Adjustment of Dispute. 26. All questions or controversies which may arise between the Contractor and the Company, under or in reference to this contract, shall be subject to the decision of the Chief Engineer, and his decision shall be final and conclusive upon both parties."

Mr. L. C. Fritch:—One thing that has not been quite satisfactory to me is the arbitration clause, the Chief Engineer representing the Railroad Company alone being the judge of the disputes between the Company and the contractor. I do not believe that that would be sustained in the courts. The question is whether we should not put into this contract the standard arbitration clause which gives each party the right to select an arbitrator and the two select the third. That seems only fair. I question if we could go into court and sustain a contention where the Chief Engineer, representing the Railroad Company, is the sole arbitrator.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—My experience with respect to the matter of arbitration clauses is that they are entirely useless. You can go into court and get your controversy settled in a much more expeditious manner with as much fairness and with about the same expense as you can by arbitration, and even if you have the arbitration clause in, it is not compulsory on the parties, and unless it is compulsory on both parties, it is useless.

Mr. R. A. Rutledge (Santa Fe):—This clause has been obsolete for a good many years. There is not a court in the land that will sustain this clause, and it has been in our contracts for years and years. I think it is wrong for this Association to carry this dead matter in its contract.

Mr. C. A. Wilson (Consulting Engineer):—I want to differ from the gentleman who says that this clause will not stand in a court of law. I

was retained recently by a Railway Company in a case where there was a suit brought for damages by a contractor. The suit was a jury case. The attorneys for the railway contended that this was not a suit in damages to be tried by a jury; but by the contract the Engineer had been constituted the arbitrator between the two parties, and he had rendered his decision as arbitrator, and that therefore it was an appeal from the arbitration of the Engineer, and the Court so held, and in view of that decision in the United States Court in Ohio, this Committee was influenced in leaving this in the conditions.

Mr. C. P. Howard (Consulting Engineer):—I have been in some law suits in which these questions have been brought up. I don't remember the courts having passed on it, but my recollection of comment of eminent attorneys on the subject is that the decision of the Chief Engineer in authority as an arbitrator would stand, unless it could be clearly proven that he had acted from fraudulent motives, or had clearly made a mistake. I think that is the way it was understood; and that we should not change it in any way until we have an opinion from an attorney.

Mr. L. C. Fritch:—I do not believe that would stand in any court. If you can put it in and get the contractor to sign it, all well and good. I do not think it amounts to much. All contracts made to-day for any large work have the standard arbitration clause in them. I think the contractor should have the chance to settle a dispute by the decision of an impartial arbitrator.

Mr. W. G. Atwood:—The Committee has a little more faith in some of the Chief Engineers than Mr. Fritch. Mr. Wilson has mentioned one case where the United States Court did uphold this clause. Another reason for the clause is that there must be someone in authority who can rule on all questions during the progress of the contract and not allow the work to be stopped or impeded, and that either an appeal to the courts or an arbitration board would necessarily or probably delay the work. An appeal can be carried either to a court or to an arbitration board after the completion of the work by agreement; but we feel it is necessary that the Chief Engineer have this power during the progress of the work to see that it is carried on.

Mr. L. C. Fritch:—All contracts made between Railroad Companies—operating contracts, etc.—have the standard arbitration clause. It is just as proper to have an arbitration clause in contracts where contractors are parties. I do not believe a Railroad Company would make a contract with another Railroad Company and allow the Chief Engineer or any officer of one Railroad Company to be the sole arbitrator. If contracts were not made with the standard arbitration clause, the courts would be pretty full of these matters. An arbitration is a more effective way and quicker settlement of disputes can be made in this way than by appealing to the courts.

Mr. J. L. Campbell (El Paso Southwestern):—I think the Engineer of the Railroad Company is up against a theory rather than a condition, and that condition is the legal department of the railroad. I think you

will find that almost invariably the legal department will insist upon this clause going into the contract, and as long as they are the final arbiters in this matter, and inasmuch as this is a clause that has always been in contracts, and has been an efficient provision for the protection of the Railroad Company, I am in favor of having it retained.

Mr. Hunter McDonald:—With respect to Mr. Fritch's example of the necessity for an arbitration clause between Railroad Companies, I do not think that is a parallel case. Railroad Companies between themselves are very loath to go into courts. They want to keep out of them as much as they can. The case is entirely different as between the Railroad Company and the contractor. They are not parallel at all. This entire contract was the subject of a very close investigation on the part of our Company by a Committee made up from our legal department and the engineering department, and with very few exceptions, the contract has been adopted as standard already. We have especially left out the arbitration clause and put in the one that is the subject of the discussion.

The Secretary:—"Order of Completion; Use of Completed Portions. 27. The Contractor shall complete any portion or portions of the work in such order of time as the Engineer may require. The Company shall have the right to take possession of and use any completed or partially completed portions of the work, notwithstanding the time for completing the entire work or such portions may not have expired; but such taking possession and use shall not be deemed an acceptance of the work as taken or used, or any part thereof. If such prior use increases the cost of or delays the work, the Contractor will be entitled to such extra compensation or extension of time, or both, as the Chief Engineer may determine.

"Changes. 28. The Company shall have the right to make any changes that may be hereafter determined upon in the nature or dimensions of the work, either before or after its commencement, and such changes shall in no way affect or void this contract. If such changes make any change in the cost of the work, an equitable adjustment shall be made by the Chief Engineer to cover the same.

"Extra Work. 29. No bill or claim for extra work or material shall be allowed or paid unless the doing of such extra work or the furnishing of such extra material shall have been authorized in writing by the Engineer.

"The price for such work shall be determined by the Chief Engineer, who may either fix a unit price or a lump-sum price, or may, if he so elects, provide that the price shall be determined by the actual cost, to which shall be added.....per cent. to cover general expense and suprintendence, profits, contingencies, use of tools, Contractors' risk and liability. If the Contractor shall perform any work or furnish any material which is not provided for in this contract, or which was not authorized in writing by the Engineer, said Contractor shall receive no compensation for such work or material so furnished, and does hereby release and discharge the Company from any liability therefor.

"If the Contractor shall proceed with such extra work or the furnishing of such extra material after receiving the written authority therefor, as hereinbefore provided, then such work or material, stated in the written authority of the Engineer shall be covered, governed and controlled by all the terms and provisions of this contract, subject to such prices as may be agreed upon or fixed by the Chief Engineer.

"If the Contractor shall decline or fail to perform such work or furnish such extra material as authorized by the Engineer in writing, as aforesaid, the Company may then arrange for the performance of the work in any manner it may see fit, the same as if this contract had not been executed, and the Contractor shall not interfere with such performance of the work."

Mr. L. C. Fritch:—I would like to have a blank left in the third line, paragraph 29, before "Engineer," so that if any Company wishes to have the extra work controlled entirely by the Chief Engineer, that might be inserted.

The President:—The Committee will accept that.

The Secretary:—"Property and Right of Entry. 30. The Company shall provide the lands upon which the work under this contract is to be done, except that the Contractor shall provide land required for the erection of temporary construction facilities and storage of his material, together with right of access to the same.

"The Contractor shall not ship any material or equipment until he has received written notice from the Engineer that he may proceed with said work or any part thereof.

"Unavoidable Delays; Extension of Time on Parts of Work. 31. If the Contractor shall be delayed in the performance of the work from any cause for which the Company is responsible, he shall, upon written application to the Chief Engineer at the time of such delay, be granted such extension of time as the Chief Engineer shall deem equitable and just.

"Suspension of Work. 32. The Company may at any time stop the work, or any part thereof, by giving ten (10) days' notice to the Contractor in writing. The work shall be resumed by the Contractor in ten (10) days after the date fixed in the written notice from the Company to the Contractor so to do. The Company shall not be held liable for any damages or anticipated profits on account of the work being stopped, or for any work done during the interval of suspension. It will, however, pay the Contractor for expense of men and teams necessarily retained during the interval of suspension, provided the Contractor can show that it was not reasonably practicable to move these men and teams to other points at which they could have been employed. The Company will further pay the Contractor for time necessarily lost during such suspension at the rate of .....per cent, per annum on the estimated value of all equipment and fixtures owned by the Contractor and employed on the work which are necessarily idle during such suspension, said rate of ..... per cent. per annum being understood to include depreciation, interest and insurance. But if the work, or any part thereof, shall be

stopped by the notice in writing aforesaid, and if the Company does not give notice in writing to the Contractor to resume work at a date within.....of the date fixed in the written notice to suspend, then the Contractor may abandon that portion of the work so suspended and he will be entitled to the estimates and payments for such work so abandoned, as provided in Section Thirty-eight (38) of this contract."

Mr. Rose:—Will this clause cover construction of a building or the installation of machinery? I think it is all right for grading work, because then you can settle with the contractor for what he has actually done and pay him for his work, and he will be damaged.

Mr. W. G. Atwood:—The Committee thinks that the contract, taken as a whole with this clause, will cover any case that they can think of, that may arise.

Mr. L. C. Fritch:—I think it would be clear and cover the point, if in place of "teams" there be added, "material and equipment."

Mr. W. G. Atwood:—That would conflict with the greater portion of the clause, because we provide for another method of payment for equipment and structures.

Mr. L. C. Fritch:—That first clause is taken from the old grading contract and would not cover in the case of a building; if the contractor has been to expense for men, equipment and material he ought to be paid for it.

Mr. Robert Ferriday (Cleveland, Cincinnati, Chicago & St. Louis):—I would recommend that the time of giving notice be left blank. A little job of grading would not amount to anything, but if a man has a million-dollar building, ten days would be pretty short notice.

The President:—The Committee will accept that.

Mr. C. P. Howard:—In reference to Mr. Fritch's remarks, this says that they will pay the contractor for men and teams when it is not reasonably practicable to move these teams to other points where they can be employed. It further says they shall pay the contractor a certain amount, per cent. per annum, on the estimated value of all the equipment and fixtures owned by the contractor and employed on the work, which are necessarily idle during suspension, at the rate of so much. That covers his fixtures, derricks and other apparatus. I do not know what Mr. Fritch means by material.

Mr. Rose:—I can answer that. I have known of cases where a company contracted for an interlocking plant, and a very expensive machine was built and stood around in the signal company's factory for a year or two because the railroad company had stopped the work.

Mr. C. A. Wilson:—That is material.

Mr. Rose:—That is part of the equipment.

Mr. L. C. Fritch:—It does not seem to me that the clause is quite consistent. In one place it refers to equipment and fixtures; in another place to men and teams. Why not make it consistent, say what he shall be paid for?

Mr. Gifford:—There is one word there that might be changed somewhat. That is the word "owned"—"equipment and fixtures owned by the contractor." Frequently the contractor rents the equipment. We would better change the word "owned" or leave it out entirely and make it read, "The value of all fixtures and equipment furnished by the contractor on the work."

The President:—The Committee will accept that.

Mr. S. S. Roberts (Consulting Engineer):—Would it not be better to state a certain fixed and predetermined rate, in regard to "compensation to be paid the contractor for men and teams, necessarily retained during the interval of suspension," etc.? If you leave that matter open to be settled after the suspension, you will probably have difficulty in agreeing upon the rate. We have always, in contracts under which I have worked, agreed with the contractor upon a fixed rate per day for men and teams prior to the signing of the contract.

The President:—That blank is susceptible of being changed if it is desired.

Mr. C. P. Howard:—The Committee consented to make that change to "equipment and fixtures provided by the Contractor." Possibly we may be going a little fast on that.

Mr. S. S. Roberts:—The portion I refer to reads: "It will, however, pay the contractor for expense of men and teams necessarily retained during the interval of suspension," etc. My suggestion is that this clause should read, "It will however pay the contractor" and then leave a blank for the predetermined rate "for men and teams."

Mr. W. G. Atwood:—The Committee hardly thinks that is necessary. This clause has to be interpreted by the Chief Engineer under the provisions of paragraph 26, and there would be just as much opportunity for disagreement about the necessity of the men and teams being retained and the practicability of moving them somewhere else as there would be over the rate, and it would ordinarily seem easy to arrive at the rate from the payrolls and local conditions at the time the work was stopped.

Mr. Geo. H. Bremner (Chicago, Burlington & Quincy):—The proper place to put in that rate is in the contract on page 702, where the statement is made, "The amount due the contractor is based on the following prices." If the contract is properly filled there will be a price made for extra work or force account and that would be the price for delays of this kind.

The President:—There is no motion before the convention.

The Secretary:—"Expediting Work, Correcting Imperfections. 33. If the Chief Engineer of the Company shall at any time be of the opinion that the Contractor is neglecting to remedy any imperfections in the work or is not progressing with the work as fast as necessary to insure its completion within the time and as required by the contract or is otherwise violating any of the provisions of this contract, said Engineer, in behalf of the Company shall have the power, and it shall be his duty to notify

the Contractor to remedy such imperfections, proceed more rapidly with said work or otherwise comply with the provisions of this contract.

"Annulment. The Company, if not at fault, may give the Contractor ten (10) days' written notice, and at the end of that time if the Contractor continues to neglect the work, the Company may provide labor and materials and deduct the cost from any money due the Contractor under this agreement; and may terminate the employment of the Contractor under this agreement and take possession of the premises and of all materials, tools and appliances thereon, and employ such forces as may be necessary to finish the work. In such case the Contractor shall receive no further payment until the work shall be finished, when, if the unpaid balance that would be due under this contract exceeds the cost to the Company of finishing the work such excess shall be paid to the Contractor; but if such cost exceeds such unpaid balance, the Contractor shall pay the difference to the Company.

"Company May Do Part of Work. Upon failure of the Contractor to comply with any notice given in accordance with the provisions hereof, the Company shall have the alternative right, instead of assuming charge of the entire work, to place additional forces, tools, equipment and materials on parts of the work for the purpose of carrying on such parts of the work, and the cost incurred by the Company in carrying on such parts of the work shall be payable by the Contractor and such work shall be deemed to be carried on by the Company on account of the Contractor, and the Contractor shall be allowed therefor the contract price. The Company may retain the amount of the cost of such work, with.....per cent. added, from any sum or sums due or to become due the Contractor under this agreement."

The President:—The Committee will insert a blank instead of the figures 10 (paragraph under "Annulment"), to agree with the other clause.

The Secretary:—"Annulment Without Fault of Contractor. 34. (a) The Company shall have the right at any time, for reasons which appear good to it, to annul this contract upon giving thirty (30) days' notice in writing to the Contractor, in which event the Contractor shall be entitled to the full amount of the estimate for the work done by him under the terms and conditions of this contract up to the time of such annulment, including the retained percentage. The Contractor shall be reimbursed by the Company for such expenditures as in the judgment of the Chief Engineer are not otherwise compensated for, and as are required in preparing for and moving to and from the work; the intent being that an equitable settlement shall be made with the Contractor.

"Notice; How Served. (b) Any notice to be given by the Company to the Contractor under this contract shall be deemed to be served if the same be delivered to the man in charge of any office used by the Contractor, or to his foreman or agent at or near the work, or deposited in the postoffice, postpaid, addressed to the Contractor at his last known place of business.

"Removal of Equipment. (c) In case of annulment of this contract before completion from any cause whatever, the Contractor, if notified to do so by the Company, shall promptly remove any part or all of his equipment and supplies from the property of the Company, failing which the Company shall have the right to remove such equipment and supplies at the expense of the Contractor.

"Failure to make payments. 35. Failure by the Company to make payments at the times provided in this agreement shall give the Contractor the right to suspend work until payment is made, or at his option, after thirty (30) days' notice in writing, should the Company continue to default, to terminate this contract and recover the price of all work done and materials provided and all damages sustained, and such failure to make payments at the times provided shall be a bar to any claim by the Company against the Contractor for delay in completion of the work.

"Monthly Estimate. 36. So long as the work herein contracted for is prosecuted in accordance with the provisions of this contract, and with such progress as may be satisfactory to the Chief Engineer, the said Chief Engineer will, on or about the first day of each month, make an approximate estimate of the proportionate value of the work done and of material furnished or delivered upon the Company's property at the site of the work, up to and including the last day of the previous month. The amount of said estimate, after deducting.....per cent., and all previous payments, shall be due and payable to the Contractor at the office of the Treasurer of the Company on or about the 20th day of the current month."

Mr. Rose:—I move that "20th" be left blank.

The President:—The Committee accepts that.

The Secretary:—"Acceptance. 37. The work shall be inspected for acceptance by the Company promptly upon receipt of notice that the work is ready for such inspection.

"Final Estimates. 38. Upon the completion and acceptance of the work the Chief Engineer shall execute a certificate over his signature that the whole work provided for in this agreement has been completed and accepted by him under the terms and conditions thereof, whereupon the entire balance found to be due to the Contractor, including said retained percentage, shall be paid to the Contractor at the office of the Treasurer of the Company within.....days after the date of said final certificate. Before the time of payment of said final estimate the Contractor shall submit evidence satisfactory to the Chief Engineer that all payrolls, materials, bills and outstanding indebtedness in connection with this work have been paid."

Mr. J. L. Campbell:—I suggest, in lieu of the words, "The date of the final certificate," in the fourth line from the bottom, that we substitute the following: "After the expiration of the time in which liens of any character may be legally filed against the work done or structures constructed under this contract." It is implied by the contract as it now stands that upon completion of the work the Chief Engineer will make

his final estimate and certificate, and, according to the contract, when that is done the final payment will be due. There may be two or three months, depending upon the locality, within which liens may be legally filed against the work.

Mr. Hendricks:—I think the bond would protect during those few months.

Mr. W. G. Atwood:—The blank space takes care of that, and also the provision that evidence shall be submitted that there is no indebtedness.

Mr. J. L. Campbell:—Until that was done, would the Company be released?

Mr. Ferriday:—The bond lies until the final completion and acceptance of the work. That would be no guarantee of something turning up after final settlement.

The President:—The general form of the bond covers the liens.

Mr. J. L. Campbell:—The El Paso Southwestern Engineering Department for some time has been somewhat annoyed by the fact that our Auditing Department is arbitrarily holding up the final estimate for a period of three months. In territory in which we are working, New Mexico and Arizona, the legal time is three months after the work has been completed for final liens. It seems to me if the Railroad Company is going to do that, the prospective contractor should have due notice in advance so he can take it into consideration in fixing his prices.

Mr. Rose:—Is not the work completed when the final certificate is made out?

Mr. W. G. Atwood:—I should say the work was finished when the certificate of acceptance was issued.

Mr. Edward Gray, Jr. (Chesapeake & Ohio):—There is some ambiguity in the last clause of paragraph 15, as now written and punctuated. "Negligence in guarding the same" seems to be put so as to exclude everything outside of it; it is a limiting clause. If that was intended we would have to use "guarding" in a too general sense. I suggest that this clause shall read, "By reason of any act or omission of said Contractor, or in consequence of any negligence or carelessness in guarding same."

Mr. W. G. Atwood:—Is it the suggestion to omit "by?"

Mr. Gray:—Yes, omit "by;" because, when "by" is used, the only class of negligence provided against is "negligence or carelessness in guarding the same."

Mr. W. G. Atwood:—The Committee will accept that.

Mr. Rose—That will not save the Company for suit on account of patents. I do not think that is covered.

Mr. W. G. Atwood:—That has been referred to the legal departments of several of the roads represented on the Committee, and they have all ruled that it did cover patents.

Mr. Gifford:—On page 708, there are two paragraphs, at the top of the page, without any distinguishing number or letter. I think they should be numbered consecutively.

Mr. W. G. Atwood:—They are a part of paragraph 33. They should be lettered.

Mr. Bremner:—It seems that this indemnity clause does not go quite far enough. It says, "by reason of any act or omission by the Contractor," whereas there may be and there are very frequently cases that arise out of the acts of the contractor that do not happen during the execution of the work. We should have a clause, "by reason of any act or omission by said Contractor, his agents or employés, in the execution of the work or arising therefrom."

Mr. W. G. Atwood:—The Committee does not see that that would make any material change in the meaning of the paragraph. We think it is covered adequately as it stands.

Mr. Hendricks:—I would like to go back to the first clause under "Bond" and suggest that the bond shall remain in force until the expiration of the time in which the lien can be filed. The time is different in the different States, and to specify the time in this way would protect against those liens and permit making the final estimate upon the completion of the work.

Mr. F. P. Patenall (Baltimore & Ohio):—It seems to me the wording of the last two lines covers what the member criticised. It says, "The work by or in consequence"—I feel that the word "consequence" would cover any later trouble that might occur after the contractor had left the work.

The President:—"By" has been cut out.

Mr. Hendricks:—I move that the last line of paragraph 1, reading, "The final completion and acceptance of the work," be stricken out, and that it read, "After the expiration of the time in which liens can be filed."

Mr. Hunter McDonald:—It appears to me that there are a few clauses in this contract which bear the earmarks of making it applicable to grading contracts only. I believe a close analysis of it will reveal the fact that it is not applicable to buildings in every respect. I refer especially to clause 32. I have no other clause in mind, but the mention of the words "Men and teams" in that clause gives it that appearance. I have found it necessary to make quite a number of alterations in the contract to make it uniformly applicable. I believe the Committee has accomplished a great work, and with a little more alteration this contract can be made adaptable to all the occasions which may arise in the Engineering Department of a railroad.

Mr. Hendricks:—My motion was in regard to the change in paragraph 1, that the second paragraph be made to read, "This bond shall remain in force and effect in such amount, not greater than that specified, as shall be determined by the Chief Engineer, until the expiration of the time in which liens shall be filed."

Mr. W. G. Atwood:—The Committee would suggest, as a substitute for that, the words, "until the final completion or acceptance of the work," be struck out, and that it be replaced by a blank, to be filled in as desired.

Mr. Hendricks:—I will accept that.

Mr. G. D. Brooke (Baltimore & Ohio):—In regard to the sentence next to the last, in paragraph 32, I suggest it be changed to read as follows: "The Company will further pay the Contractor for time necessarily lost during such suspension at the rate of blank per cent. per annum on the value, estimated by the Engineer, of all equipment and fixtures, owned by the Contractor," etc.

That fixes a way in which the value of the equipment is to be determined. The rate at which the payment is to be made is specified, but no provision is made for determining the principle on which this rate is to be paid.

Mr. Hunter McDonald:—In respect to this matter, the contractor is to be allowed a percentage on equipment and fixtures only in the case of buildings. He may have steel beams, lumber, terra cotta, cement, and all manner of material piled up on that work and it may lie there a year and he gets no compensation whatever. I think that clause should be revised.

Mr. L. C. Fritch:—That is the point I tried to bring up some time ago, that it is an old provision, and does not cover the general conditions under which this contract shall apply.

Mr. W. G. Atwood:—That will be cared for by the insertion of the words, "and materials," after "fixtures."

Mr. C. P. Howard:—Let me ask if the contract does not elsewhere provide payment for the materials delivered?

The President:—Mr. Fritch, do you think that insertion meets the point that you make?

Mr. L. C. Fritch:—I have been trying to get those two teams out of there. I think it will be covered if you put "men and equipment" in there instead of "material and equipment."

Mr. Lloyd:—Paragraph 36 says the materials shall be paid for. I do not understand why he should get additional compensation for the materials, inasmuch as they are already paid for on monthly estimates.

Mr. W. G. Atwood:—Materials delivered prior to the first of the month during which the suspension might take place would be paid for under the estimate. If we add the word "materials" in this clause, it would cover interest on materials after that time and during suspension.

Mr. Hunter McDonald:—The point is that interest is not full compensation for having material lie idle. Cement may be damaged by dampness and lumber may be damaged by exposure to the weather. It is necessary that the contractor shall take care of it during the interval of suspension, and he ought to be paid for that.

Mr. C. P. Howard:—The contract stipulates that per cent. shall cover depreciation.

The President:—The Committee thinks that Mr. Howard's statement covers the case. It is possible to leave out the per cent. entirely if it is so desired. There is no motion before the house.

Mr. Brooke:—I desire to make a motion; that is, that the sentence under discussion be changed to read as follows: "The Company will

further pay the Contractor for time necessarily lost during such suspension, at the rate of blank per cent. per annum on the value, estimated by the Chief Engineer, of all equipment and fixtures owned by the Contractor," etc.

Mr. Rose:—I do not believe we want that in. This is the equipment and fixtures on the job that are idle. The contractor might take his equipment somewhere else and work with it.

Mr. W. McC. Bond (Baltimore & Ohio):—We have already agreed to change this and make it read "Material on the work"—"fixtures on the work." I think that is already covered.

Mr. W. G. Atwood:—I would move the adoption of the contract form as amended and that it be published in the Manual as recommended practice.

Mr. Gifford:—In seconding the motion I want to say that this contract form has been submitted to more than twenty bridge builders and structural steel fabricators, and with the exception of what I mentioned early in the discussion, no objection has been raised to it. I think I can say for these people that should this contract be adopted, as I hope it will be, they will be only too glad to sign it with alacrity whenever they have opportunity.

(Motion carried.)

The President:—The motion is carried and this form is adopted. There is only one other thing the Committee has; that is, articles Nos. 1 and 2 under Recommendations. The harmonizing of contract forms between Standing Committees. Probably that is matter for the Board of Direction to urge upon all committees that they do their best to make their recommendations comply with this. It may be taken therefore as a suggestion on the part of this Committee. The second is the suggestion by the Committee that they be discharged on account of the completion of the work assigned to them.

Mr. Rose:—I do not believe the Committee is through. I think that a form should be prepared by this Committee for proposals, so that the railroad companies can submit that form to contractors for equipment. I find that the various companies furnishing electrical equipment have their own forms, and each one is a little different. I have found in some forms some paragraphs that are objectionable. With this contract form as adopted there should go a blank for proposals. I think the Committee should get up a form of bond. The company I am connected with have a form of bond that they hand to the contractor and they make it out and it serves the trouble of having it approved by the legal department.

The President:—Mr. Wendt, we would be glad to hear from you on the point of discharging this Committee.

Edwin F. Wendt (Pittsburgh & Lake Erie):—The Committee was appointed for one general purpose, viz., to draw up a uniform general contract form. If it is the judgment of the Committee that they have completed that work, we should discharge them. If the suggestion made

by Mr. Rose is one that should be followed out to completion, the Committee should be continued. This contract form will likely require some revision during the next few years, because every conclusion, when tried one or two years, needs some revision. If such should be the case during next year, the Committee would find work to do. It might be well to continue the Committee in a consulting capacity.

Mr. Hunter McDonald:—In support of what Mr. Rose has stated, I agree with him and I think a proposal ought really to be a part of the contract, and when it is signed by the contractor, the only thing necessary to complete the contract is for the Engineer to sign it. In other words, the proposal should be embodied in the contract and the entire thing submitted with the proposal. We use that method now, and I think the proposal and the bond are absolutely essential to the completion of this Committee's work. I hope they will keep it up.

Mr. George W. Kittredge (New York Central & Hudson River):—If I did not have ample confidence in the Board of Direction, and if I did not think that the Board would in its wisdom continue this Committee, I should make a motion that the Board be instructed so to do; but having that confidence, I have no motion to make.

The President:—I think under the circumstances we should relieve the Committee with the thanks of the Association for the valuable work done. The Committee is relieved.

DISCUSSION ON WOOD PRESERVATION.

(For Report, see pp. 711-726.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WOOD PRESERVATION.

EARL STIMSON. DR. H. VON SCHRENK.

The President:—The report of the Committee on Wood Preservation will be presented by the Chairman, Mr. Earl Stimson.

Mr. Earl Stimson (Baltimore & Ohio):—Taking up the "Consideration of the Specifications for Fractionation of Creosote Oil," I will ask Dr. von Schrenk to present the subject.

Dr. H. von Schrenk (Consulting Timber Engineer):—The experiments to which the Chairman refers were made as a result of a number of inquiries which came to the Committee last year, as to whether the standard practice now printed in the Manual for fractionating coal-tar creosote was the best method for conducting this operation, and in order to secure fuller data on the subject the Committee sent out two separate creosote oils to a number of railroads, with the request that they analyze or fractionate these samples according to the standard methods now printed in the Manual, and according to a suggested method of using a flask instead of a retort which had been presented by a sub-committee of this Committee two years ago. The oils were labeled respectively A and B. The samples all came from the same can, and the methods prescribed by the Manual and by the recommendation made to the Committee two years ago were followed by various operators for various companies. The results have been tabulated in the report this year. A careful study was made. First as to the variations in results between the two methods *per se* and then a study of the variations due to the fact that different individuals were using one and the same method. After a careful tabulation of these variations, the Committee came to the conclusion that the present method as printed in the Manual showed a variation which was slightly less (from the personal variation standpoint) than that obtained in the fractions made with the suggested method. The Committee could find no evidence of any improvement which could be obtained by the suggested method, over the one which is printed in the Manual at the present time. In order that these results might once and for all be available to those interested in the subject, we have presented in full the actual results submitted by the individual operators.

Mr. Stimson:—I will say in explanation of form "A" that it provides a record of the treatment and the determination of the absorption by gage readings. Form "B" provides a record for the determination of the absorption by weighing. Form "B" provides a check against

form "A." I move that these forms be adopted for insertion in the Manual.

(Motion seconded and carried.)

The President:—This disposes of the report of the Committee on Wood Preservation, and unless there are further remarks, the Committee will be relieved, with the thanks of the Association.

DISCUSSION ON TIES.

(For Report, see pp. 727-790.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON TIES.

L. A. Downs. F. R. Layng.

The President:—The report of the Committee on Ties will be presented by the Chairman, Mr. L. A. Downs, and he will explain the action to be taken by the convention.

Mr. L. A. Downs (Illinois Central):—The Committee on Ties was assigned the four subjects which are shown on page 727, three of which are reported upon. The conclusion in regard to design of tie-plates and track spikes is shown on page 729, last paragraph, in which the Committee says: "The Committee was unable to obtain any definite information bearing on the relative effect of the different designs of compound tie-plates and spikes on the life of ties, but it is thought that experiments which are now being conducted will throw some light on this subject in the near future."

It was found in making an investigation on this subject that nearly every Engineer who has charge of maintenance of a railroad has different ideas in regard to tie-plates, so that we thought we would not have the Association lose the result of the labor we put on this in the last year, and the following twelve pages, commencing with page 730, are devoted to the replies that were received from the different railroads. It contains some valuable information to anyone who is interested, including the designs of the plate used by the different railroads. There are some railroads that are conducting experiments, the Baltimore & Ohio, the Santa Fe and some others, and when these experiments are concluded the Committee will be able to furnish you with some valuable information on this subject.

The next subject assigned to the Committee was that on "Metal, Composite and Concrete Ties," which is given on page 742, and I call your attention to the paragraph which reads as follows: "The Committee is building up in your Proceedings a history of the development of the substitute tie. It will be noticed that no ties are reported on unless the same have been put in actual use by some steam or electric railroad. We expect to be able from time to time to record the history of the development of all substitute ties that are in use."

I call your attention to the use of the Kimball Concrete Tie, for the reason that Mr. Kimball, who is a member of our Association, wrote the Secretary and stated that the ties that he referred to were put in once before, and in order to give all the information that is possible we have had the chairman of the sub-committee, Mr. Layng, make a note regarding this tie, which he will read.

Mr. F. R. Layng (Bessemer & Lake Erie):—The tie was installed on the Pennsylvania Lines, Southwest System, and had been previously installed in 1902, one mile east of Saginaw, Michigan, on the Pere Marquette Railroad.

Mr. L. A. Downs:—The next subject assigned to the Committee was "Continue study of the stresses to which cross-ties are subjected, and determine size required."

The sub-committee wrote to 27 members of this Association for some enlightenment or suggestions they might give in regard to it, and of those 27, 15 replied. Probably some of you have read their replies, which are in this report, and it will show how hard it was for this Committee to get at the work, and you will find, commencing on page 768, and continuing to the end of the report, the work that the sub-committee did on this. It shows considerable research work and considerable progress. We went back to all the authorities that we could find in regard to the stresses in ties, and the conclusion in regard to this subject is found on page 782, which is just above Exhibit A.

I notice the report of the Committee on Ballast recommends something similar in ballast, and it might be that the Board of Direction in figuring this out might combine the work of the two committees in some way.

The reports on the three subjects which I have given you are in the nature of progress, and our report is presented as information, and I move that the report of the Committee be received as such.

(Motion carried.)

The President:—This Committee has made available to this Association a very large amount of valuable information, and it is thought by the Directors that it will lead up to more detailed work by the Committee during the coming year, and we know that this Committee is prepared to continue this investigation. The Committee is excused with the thanks of the Association.

Mr. Duncan MacPherson (National Transcontinental—by letter):—The Committee has put together in convenient form for reference very considerable information in regard to studies made by Cuenot, Bräuning, Wellington and others, and in addition, have got the practical views of a number of leading railway men. The consensus of these opinions quoted, of scientific and practical men, supports the Committee's conclusion in regard to spacing ties from 10 in. to 12 in. face to face.

A tie with 7 in. to 9 in. face and 7 in. depth seems also most in favor, and the writer believes, with the Committee, that such dimensions and spacing would be good practice on a standard road having heavy traffic. There remains only the length of tie to be considered, and as this has been about 8 ft. from the beginning of standard gage, and the limit of close spacing has been reached, lengthening the ties is the only way left to increase the supporting area and decrease the unit pressure upon the ballast and subgrade.

It seems very necessary to increase the foundation area supporting track, when the weight of rolling stock has been increased from 200 to 300 per cent. during past 20 years, and the only increase in track supporting area has been about 33 per cent., due to the closing up ties from about 24 in. to 18 in. centers.

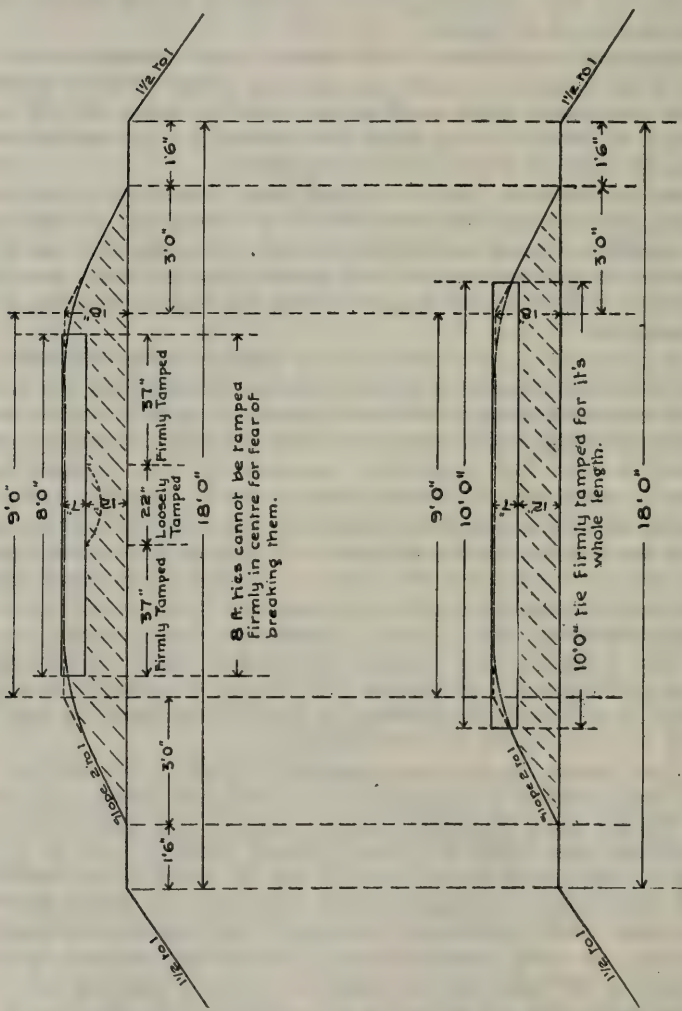
Mathematical calculations of tie stresses are of doubtful utility, because of the number of variable and unknown factors in actual practice, so that experiments under actual service conditions seems the only reliable way of getting accurate data. The difficulty is to get railway companies to supply the funds for such experiments.

The investigations made by Ast and Blum, referred to in the Committee's report, indicate that ties 8 ft. 10 5/16 in. long, 10¼ in. wide, give good results on German and English railways, where axle loads are much less than on this continent. These investigators also state that "the superiority of the long, stiff sleeper becomes more apparent the less good the ballast is."

Of course the length of ties is not so important when rock ballast is used, but as the majority of railways still use gravel ballast, the writer would suggest that some of the leading railways might, or should, make experiments under actual service conditions on short sections of track with 10 ft. ties. This length gives practically the same distance from center of rail to end of tie and center of track, and while giving 25 per cent. more supporting area than an 8 ft. tie, would not require much, if any, more ballast, as the ordinary 15 ft. base of ballast with convex top would be sufficient for this length of tie, and the increased length of tie would occupy space otherwise occupied by ballast. (The attached drawing illustrates this.) Ten ft. seems the logical length, as the functions of the tie are to hold the rails in place relative to each other, and to distribute the loads through the ballast to the subgrade in such a manner as to prevent the crushing of the ties abnormally far into the ballast or of the ballast into the subgrade.

If we assume the ties sawn completely through at the center of the track, and spreading of track prevented by steel rods bolted to the rails, then the ties would only have to support the axle loads applied vertically through the rails. Eight ft. ties cut in center would project 2 ft. 5½ in. inwards from center of rail, and 1 ft. 6½ in. outwards, and doubtless these outer ends would sooner crush down into the ballast than the inner ends. With 10 ft. ties the length each way from the rails would be practically the same, and would surely equalize and minimize the unit pressure on the ballast and the subgrade. It would doubtless cost more for the longer ties, but at present prices they cost per mile only about 35 per cent. of the cost of 80-lb. rails and fastenings, and the weights of the latter are constantly increasing. The life of this more expensive part of the track and rolling stock could be considerably increased, with the better track conditions due to longer ties, so that it would seem true economy to spend a little more on ties rather than to continue increasing the cost of the expensive superstructure while leaving the comparatively cheaper foundation defective.

DIAGRAM ILLUSTRATING HOW TIES 10 FT. 0 IN. LONG MAY BE USED IN AN ORDINARY BALLAST SECTION FOR 8 FT. TIES WITHOUT REQUIRING ANY EXTRA BALLAST.



Note:—Eight ft. ties tamped firmly for 16 in. each way from rails only utilizes the supporting area of 77 per cent. of tie equal to 74 in. in length, or 740 sq. in. for a tie of 10 in. face.

Ten ft. 0 in. ties could be used in the same ballast section, firmly tamped for the whole length; giving the maximum supporting area of 1,200 sq. in., or equal to 162 per cent. the efficiency of 8 ft. ties.

DISCUSSION ON SIGNS, FENCES AND CROSSINGS.

(For Report, see pp. 791-830.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON SIGNS, FENCES AND CROSSINGS.

F. J. Bachelder.
J. L. Campbell.
A. W. Carpenter.
Robert Ferriday.
Richard L. Humphrey.
J. B. Jenkins.
S. A. Jordan.
F. P. Patenall.
E. V. Smith.
C. H. Stein.

The President:—The report of the Committee on Signs, Fences and Crossings will be presented by the Chairman, Mr. C. H. Stein.

Mr. C. H. Stein (Central of New Jersey):—The Board of Direction assigned to this Committee for consideration during the past year the following subjects:

"(1) Report on the relative advantages of the different kinds of fence posts, with definite recommendations.

"(2) Report on the best form of track construction and flangeways at paved street crossings and in paved streets, with definite recommendations.

"(3) Continue the investigation of ways and means for securing a proper quality of fence wire to resist corrosion and secure durability."

You will observe in two instances that the Board of Direction indicated a growing impatience with the Committee in not seeming to at least endeavor to dispose of these two subjects that have been given it for the past several years. The Committee aimed, in view of the fact that it was the only one of the committees that had received such mandatory instructions, to gather together everything available that had reference to these subjects; they investigated the matter of the different kinds of posts made from wood, steel and concrete, collecting such data as they could from the railroads and securing all the information that was available on this subject, with a view of presenting definite recommendations.

It seems to us that this particular subject pointed inevitably to the consideration of concrete for fence post purposes and after considering all the available information the Committee embodied its ideas in a series of conclusions which will be found on page 816:

(1) Concrete posts are practical, economical and a suitable substitute for wood.

(2) Reinforcement should be placed as near to surface of post as possible; ½-in. from surface is best location.

(3) Post should taper from base to top.

(4) Post should not be less than 5½ in. at base and 4 in. at top.

(5) Concrete mixture should consist of one part cement to four of run of pit gravel; or one part cement, two parts sand and four parts

crushed rock or screened gravel. Gravel or crushed rock not to be smaller than ¼-in. in size, nor larger than ½-in. Concrete should be of a quaking consistency.

(6) Molds should have a jogger or vibratory motion while concrete is being introduced to compact it and smooth up surface of post.

(7) Posts should not be made out of doors in freezing weather. They should not be exposed to sun, and should be sprinkled with water the first eight or ten days after being made to aid curing.

(8) Molds should be carefully oiled or soaped to provide a smooth finish and to prevent concrete sticking to mold.

(9) Posts should be cured for not less than 90 days before being set or shipped.

(10) Posts should be carefully handled and be packed in straw, sawdust or other suitable material for shipment.

It is to be borne in mind that concrete posts are proprietary articles, and not a great deal of progress has been made among the railroads yet in the consideration of them. There are very few who have gone very largely into the matter, although it seems as if it is growing very rapidly and that better information will be developed in the course of a few years. The farming communities have been more largely users of concrete posts than the railroads. We have endeavored to avoid, as far as possible, any references to the names of the manufacturers of these posts.

We have presented these conclusions as some cardinal principles governing the manufacture of the posts.

Mr. Richard L. Humphrey (Consulting Engineer):—There is one very essential point which I think the Committee has overlooked. It is recommended that the reinforcement be placed one-half inch from the surface and it is further recommended that gravel or crushed rock should be used as an aggregate. I think it will be found where the crushed stone is rather soft or has high absorptive qualities, that there may be trouble encountered through the corrosion of the reinforcement of the post. The gravel or crushed stone used in the post should be hard, dense material, with low absorption, otherwise it may be the means of developing corrosion of the reinforcement and the final destruction of the post.

Mr. Stein:—You understand that these are conclusions only.

I move the adoption of these conclusions, which have been read, sections 1 to 10, and also the recommendations that the conclusions be substituted for those in the 1911 Manual of Recommended Practice.

The President:—The conclusions in the Manual, heretofore adopted, are quite indefinite compared with these and those now submitted are certainly an improvement.

Mr. Humphrey:—I suggest that we put in the fifth conclusion, "gravel or crushed rock of low absorption."

The President:—The Committee will accept that.

Mr. Robert Ferriday (Cleveland, Cincinnati, Chicago & St. Louis):—Does the Committee consider it essential or necessary to require, in conclusion 6, that the molds should have a jogger or vibratory motion?

Their idea, as I understand, is to make the surface of the post smooth. Is that the only way that a smooth post can be made?

Mr. Stein:—I might say, in regard to that point, as I remarked in presenting this report, these posts are proprietary articles. The railroads have just begun to use the concrete post, and the experience of those railroads, so far as we could learn, who had used the different kinds of posts, is, that those railroads which use molds with the jogger or vibratory motion turned out the best posts, and also that these posts are the most compact; the Committee concluded that, at this time, in the present state of the art, until we get something different, that it is a very essential feature. I believe the United States Government has made some experiments and has reached the same conclusion. Jogging has a tendency to compact the concrete and make it proof against the infiltration of water.

Mr. Humphrey:—The Committee recommends concrete of a quaking consistency. It is my opinion that there is a tendency to make the concrete too wet, and the result is water voids in addition to air voids, which decrease the density of the concrete and, therefore, the strength of the post. It would seem to me that there should be a definite period of time for mixing the concrete, so as to reduce as much as possible the air and water voids. It is possible in this way to secure a concrete of quaking consistency with much less water, which, when vibrated in the mold, produces a concrete of maximum density. The vibration of the post recommended by the Committee is excellent and with a well-mixed concrete great strength may be attained.

Mr. Stein:—I will answer by saying that the experience of those who have engaged in the manufacture of concrete posts is just to the contrary, and it has been almost the uniform experience of those who have been making posts, that the concrete should be at least of a quaking consistency, and some very good posts that are turned out are made under a specification that "you shall be able to pour the concrete." The Committee did not see that it was warranted in taking the advance ground that the manufacturers of this very good concrete post took and the Committee thought it was only warranted at this time in specifying that it should be a quaking consistency. We realize that perhaps these are not the best specifications that can be gotten up. Solon, the great law-giver of Greece, in presenting the first laws to the Grecians said, when asked if they were the best he could prepare, "No, they are not the best I can prepare, but they are the best that you are willing to accept." While these specifications may be improved, I do not believe if we made them more radical they would be considered.

This is the first advanced step we have endeavored to take upon the subject of concrete fence posts. We have had a series of principles before that really did not deal with posts, except in a very remote sense. We have tried to present this time something that will be acceptable, but we realize we have only scratched the surface. As the Illinois Central, the Chicago, Burlington & Quincy and the Rock Island roads have undertaken investigations in the matter of the construction of

concrete posts, we hope to get information from those companies which will enable us to present more definite detailed information in our next report, but we did not feel that we could go further at this time.

Mr. Humphrey:—I do not wish to be misunderstood, I am not a believer in dry concrete; I believe that there is a tendency to make concrete entirely too wet, the effect of which, especially in small pieces of concrete like a fence post, is to so increase the percentage of air and water voids as to materially decrease the strength and by using less water and mixing longer, much better results are obtained. My remarks are not intended in any way as a criticism of the report, but rather for the purpose of offering some suggestions which may be of value in making satisfactory fence posts. I wish to compliment the Committee on the excellent work it has done, covering, as it does, the essential points.

Mr. S. A. Jordan (Baltimore & Ohio):—I ask why, in conclusion 9, the posts should be cured for not less than 90 days before being set or shipped?

Mr. Stein:—It is the opinion of manufacturers of concrete posts, and I say this with the support, I believe, of every manufacturer of concrete posts, that under all circumstances they should be cured for not less than 60 days. That means a seasoning process, and while it would appear that a small mass of concrete like a post would dry out or season and cure within a comparatively shorter period of time, it has been found by experience that it is not the fact, and that it really requires at least 60 days, and the statement is made that 90 days is preferable in every case, before the concrete post reaches its full strength, and even after that it continues to grow in strength, and the experience is similar with respect to other forms of concrete. We thought we would be on the safe side and specified 90 days. If the users desire to cure the concrete for only 60 days, that is a matter within their own control and they can substitute 60 days for the 90 days.

Mr. Humphrey:—The Committee should consider the question of steam curing. With a proper system of steam curing, the interval between the manufacture and use of the post is materially reduced.

Mr. Stein:—That would be necessary where the concrete posts are made indoors in the winter time, but the Committee did not care to go into that subject at this time.

Mr. E. V. Smith (Baltimore & Ohio):—In conclusion 7 the Committee says that the posts should not be exposed to the sun. Why should that not read, "should not be exposed to sun or artificial heat?" Why not have that apply to artificial heat also in extreme weather?

Mr. Stein:—Some manufacturers of concrete posts cure their posts by steam—that would be the application of artificial heat. The Committee thought it would not be well to make any modification in that conclusion at this time. The object of not exposing the posts to the sun is to prevent the cracking or alligatoring of the posts. There is also a provision in conclusion 7 that the posts should be sprinkled. That is to allow for the complete absorption of the moisture and the compacting of the material and the seasoning of it.

Mr. Humphrey:—I think conclusion 9 should have an explanatory note. I take it that the 90 days applies to natural curing; where steam curing is used, the time would, of course, be much less. I understand these recommendations will go into the Manual and I believe, therefore, this explanatory note is essential.

The President:—What would you suggest, Mr. Humphrey?

Mr. Humphrey:—I would suggest a note be added reading, "90 days when cured naturally."

The President:—The Committee will accept that.

Mr. F. J. Bachelder (Baltimore & Ohio):—I do not see any provision with reference to the fastening of the wire on the posts.

Mr. Stein:—That is one of the things about which we did not care to go on record, that is, the various methods of fastening wire on concrete posts. The generally accepted method of doing this is to use the Western Union twist, taking a tie wire and tying it with the Western Union wrap. If you will read the text of the report you will see that the method is mentioned in many instances, but we did not feel like going on record in regard to it. There are other less approved methods of attaching the wire. The Committee is waiting for developments and we did not feel like mentioning any of the methods specifically.

(The motion to adopt the recommendations of the Committee, covering conclusions 1 to 10 and also the publication of the conclusions in the Manual, was adopted.)

Mr. Stein:—The second subject referred to the Committee was "Track Construction and Flangeways at Paved Street Crossings and in Paved Streets."

The Committee got in touch with all the railroad companies from whom we could get information, and we secured plans. As I primarily stated, the Board of Direction has assigned us this subject for a number of years now and this past year they asked us for definite recommendations. We presented specifications once before to cover the subject, but when we came to get up plans to harmonize with these specifications we found ourselves in deep water; we could not make plans that would match the specifications. We secured all available data, and it was our conclusion that the form of track construction and flangeway at paved street crossings and in paved streets should be as shown on page 823. We concluded that the form shown on that page would embody the requirements which would best meet the various situations.

We have prepared specifications covering this form of track construction and these specifications are given in the form of conclusions on page 825:

"(1) Specifications for best form of track construction and flangeways at paved street crossings and in paved streets:

"Treated ties should be used, laid on a bed of crushed rock, gravel or other suitable material, not less than 8 in. nor more than 12 in. in depth, placed in about 3-in. layers, each to be thoroughly rammed to compact it.

"Vitrified tile drains not less than 6 in. in diameter, with open joints, leading to nearest point from which efficient drainage may be obtained, or with sufficient outlets to reach sewers or drainage basins, should be laid on either side of and between tracks, parallel with ballast line and outside of ties.

"141-lb., 9-in. depth girder rail, or similar section, with suitable tie-plates and screw spikes should be used. Track should be filled in with crushed rock, gravel or other suitable material, allowing for 2-in. cushion of sand under finished pavement.

"Ballast should be thoroughly rammed as it is installed for paving foundation to settle it. Two in. of good sharp sand should be placed on top of ballast.

"Paving must conform with municipal requirements, granite or trap rock blocks preferred. Hot tar and gravel should be poured into joints as a binder.

"(2) The inclusion in the Manual of the accompanying plan."

Mr. E. V. Smith:—Why should we specify, in the first paragraph, a maximum depth of not more than 12 inches? I think that should be omitted.

Mr. Stein:—There may be some remote cases where more than 12 in. are necessary, but where you have fairly good supporting ground and you put in more than 12 in. you may have to resurface the track more frequently on account of the gradual settlement or compacting of the ballast. The experience of the New York Central Lines has been that they do not even put in as much as 8 in. They put in in one case only 3 or 4 in., and claim to have gotten excellent results, while where they put in more it was the only place the track settled to any appreciable extent. I realize the fact that it is not exactly in harmony with good theory or even good practice. I realize that the investigations of the Ballast Committee have shown that the greater the depth of ballast the more evenly the load is distributed, but this is the result of the experience of those roads which have tried it, and we have felt that from 8 to 12 in. was a proper margin.

Mr. J. L. Campbell (El Paso Southwestern):—I am surprised to know that even 8 in. of ballast will properly support a railroad track across a paved street, without a degree of settlement which will injure the pavement. I ask if the Committee has any information as to what extent cities will permit that form of construction. In El Paso they require a solid concrete foundation and on our own account we have found it desirable, at least, if not absolutely necessary, to have the track in perfect surface, so that they will not have to repair the crossing frequently, and for that reason we make a solid concrete foundation.

Mr. A. W. Carpenter (New York Central & Hudson River):—The drawing on page 823, as I understand it, shows the recommended construction, and shows a concrete packing around the rails. I wondered if that was for the purpose of preserving the rail from corrosion or merely a detail in connection with the pavement. Nothing seems to be said about it in the conclusion.

Mr. Stein:—That is simply a detail in connection with the paving and has no reference to the rail. It was not included in the specifications, for the reason that the recommendation was that the plan accompany the specifications, and some other material might be put in, for instance, tar and gravel, or something of that nature, and I believe some roads do put a compacting material of a bitulithic or asphaltic nature along the rail. We concluded that would show up on the plan and if some other form of material is desirable, there would be no objection to it.

Mr. A. W. Carpenter:—Is not some such preservative material desirable, if not necessary?

Mr. Stein:—It may be, but I am not prepared to say.

Mr. J. L. Campbell:—Could the Committee have any objection to adding to the second paragraph of the specification, "except where a concrete foundation is necessary or required?"

Mr. Stein:—We do not feel as if we wanted to make any reference in the specifications to the concrete base. We did not feel that the concrete base was the best form of track construction, nor was it economical. It is very expensive, and when the time comes for a renewal, it practically means a tearing up of the entire street, and right here in the busiest part of Chicago, in connection with some of the concrete work done in streets, they do not put in a concrete base for that very reason; when the time for renewal came there would be great interference with traffic in the street. There are many reasons why a concrete base is not the best thing under steam traffic. We believe it is the general practice on interurban traffic and on the street car lines to put in a concrete base, but it is an open question as to whether that is the best practice for steam railroad construction, and those who have tried it have found there are quite a number of objections to it, and we do not feel as if we wanted to take into consideration the concrete base at this time.

Mr. F. P. Patenall (Baltimore & Ohio):—In view of the explanation made by the Chairman of the Committee, I would suggest that where "concrete packing" is specified, it be left blank, or a note be inserted "as specified."

Mr. Stein:—One of the members of the Committee calls attention to the fact that the points we have been talking about are covered in the text of the report. If members had read this paper they would have learned something about it in better form than I can express it.

Mr. Patenall:—At the bottom of page 825, under "Recommendations," we are asked to have this included in the Manual, and I suggest that if there are other parts of the report which refer to concrete packing, that the matter should be corrected and the reference made to correspond to the plan on page 823.

Mr. Stein:—The Committee will withdraw the note "concrete packing" and just say "form of packing."

Mr. Robert Ferriday (Cleveland, Cincinnati, Chicago & St. Louis):—It seems to me that it is unnecessary and contrary to what we know about ballast to specify that there shall not be more than 12 in. of ballast.

The Pennsylvania Railroad made tests, and I think the Committee on Ballast made some report, in which they showed that an increase of the ballast to a thickness of perhaps 18 to 24 in. reduced the cost of maintenance. In explanation of why that is given as a maximum of 12 in. in the specifications before us it is said that some of the New York Central track settled where they had 12 in., but did not settle where they had 4 in. I think in the case of any fresh track put down we would have to wait some time until it settled, and that it might possibly take a longer time with a deeper ballast than 12 in., but it does not seem to me that it is desirable to go on record and put in the Manual that 12 in. should be the maximum. I, therefore, make a motion to omit the words, "nor more than 12 in.," in the second paragraph.

The President:—The Committee will accept that.

Mr. J. B. Jenkins (Baltimore & Ohio):—I suggest changing the plan to conform. There is a note on the plan which reads, "8 to 12 in. of ballast." That should be "not less than 8 in. of ballast."

(Motion to adopt the specifications as amended was carried.)

Mr. Stein:—The third subject to be considered is "Continue the investigation of ways and means for securing a proper quality of fence wire to resist corrosion and secure durability."

Unfortunately, the tests which were being conducted at Carnegie Institute at Pittsburg were abandoned some time ago. If those tests had been continued we would have had an opportunity to learn something with regard to fence wire. We will have to learn it from our own experiences, unless some other tests are undertaken. One member of the Committee has been conducting some tests, and he has secured some valuable information, but we do not consider it worth our while to continue the subject any further. We therefore recommend to the Board of Direction the discontinuance of this subject.

The President:—It is hardly necessary for action to be taken on that recommendation, unless the members wish to say something to the contrary and do not agree with the Committee.

Mr. Stein:—With regard to the second recommendation, that is, to the effect that the Board of Direction assign to the Committee the investigation of the various kinds of signs for railroad purposes as applicable to both the employe and the public, the Committee was persuaded to make this recommendation because of the fact that the Public Utilities Commissions of the various States have gone into a consideration of this subject and desire to prescribe in a great many cases just what kind of signs should be put at railroad crossings, etc., and a number of the members of the Association suggested to the Committee that the subject should be discussed, and we thought it was an opportune time to present it to the Association, believing if the convention passed favorably on it, the Board of Direction would take cognizance of the fact.

The President:—The Board of Direction will take cognizance of this recommendation. The Committee has the thanks of the convention for the admirable way in which they have presented this subject, and they are relieved with the thanks of the convention.

DISCUSSION ON MASONRY.

(For Report, see pp. 831-838.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON MASONRY.

RICHARD L. HUMPHREY. F. L. THOMPSON.
C. H. STEIN.

The President:—The next report which we will consider is the report of the Committee on Masonry. In the absence of the Chairman of the Committee, Mr. Tinker, the report will be read by the Vice-Chairman, Mr. F. L. Thompson.

Mr. F. L. Thompson (Illinois Central):—The Chairman of the Committee, Mr. Tinker, has been ill practically all of the year, and the work of the Committee has been handicapped on this account. The report of the Committee, while it is in good shape, is not in proper condition for publication, and the Committee expects to get the matter in better form by the next meeting.

(Mr. Thompson then read the preliminary portion of the report.)

The Joint Committee on Concrete and Reinforced Concrete submits its second report, and recommends that the Association take the same action as was taken with the first report, namely, that it be received as information and distributed in printed form among the members of the Association.

The Committee also desires to state that the Appendix A has been printed without the consent of the Committee and requests that it be withdrawn.

Mr. C. H. Stein (Central of New Jersey):—I move that the report of the Committee be received as a report of progress.

(Motion carried.)

Mr. Richard L. Humphrey (Consulting Engineer):—I move that the report of the Joint Committee on Concrete and Reinforced Concrete be received as information.

The President:—The Committee recommends that this report be printed and distributed. The Board will take action on that, and we will be glad if you receive this report as a report of progress. It is also understood that Appendix A is withdrawn, if there is no objection.

DISCUSSION ON ELECTRICITY.

(For Report, see pp. 987-1012.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ELECTRICITY.

GEORGE W. KITTREDGE.

The President:—The report of the Committee on Electricity will be presented by the Chairman, Mr. George W. Kittredge.

Mr. George W. Kittredge (New York Central & Hudson River):—Your Committee on Electricity this year presents a report which we hope will be found to contain interesting information. The report is one of progress and information. The Committee has no conclusions to present which require formal action by the convention. We have, however, two corrections which we desire to have made in the report.

On page 988, under the heading, "Transmission Lines and Crossings," we desire to have the second paragraph of that section read: "Your Committee, however, is not prepared at this time to make any further recommendations for the reason that more time is required to study the development of the art in respect to voltages over 70,000, and further, because of the fact that all of the various similar associations have not yet modified theirs or formally adopted ours so as to make a uniform specification. We know of no reason, however, why those that have not should not do so as opportunity for revision comes up. In other words, our specifications are not objectionable."

On page 989, we want to substitute for the members of the joint committee, appointed by the American Electric Railway Association, Messrs. Townley, Richey and Palmer.

A good deal of work has been done during the year. Nearly all of the members of the Committee have been active and interested, and each has done his part in the work.

The subject, even to us who have been in it most deeply, is in its early stages, yet we believe as time goes on valuable information will be at hand for presentation to the Association.

The President:—If there is no objection, the changes desired by the Committee will be made and the report accepted. If there are no further remarks, the Committee will be relieved, with the thanks of the Association.

AMENDMENTS

AMENDMENTS TO COMMITTEE REPORTS.

REFERENCE TO AMENDMENTS MADE TO COMMITTEE REPORTS AT THE FOURTEENTH ANNUAL CONVENTION.

RULES AND ORGANIZATION.

(For Report, see pp. 65-70; discussion, pp. 1021-1045.)

Amend clauses (17) and (19) to read as follows:

"(17) and (19) Any action proposed by State, County, Township, Municipality or other authority, which will in any way affect the Company, shall be reported immediately to the .....(Title)..... "

Amend clause (27) to read as follows:

"(27) When tie-plates are used, they shall be applied so as to secure a full bearing on the tie and for the rail."

Amend clause (28) to read as follows:

"(28) Uniform gage is essential to good track and must be maintained."

Amend clause (29) by substituting "six degrees" for "eight degrees."

Amend clause (31) by substituting the word "elevation" for "superelevation."

Omit the phraseology following the word "standards" in the second line and substitute a notation referring to the standards of the American Railway Engineering Association.

Amend the heading "Switches" to read "Switches and Frogs."

Amend clause (35) to read as follows:

"(35) Switch points must fit closely and accurately to the stock rail, and the stock rail must be bent in accordance with the standards." Add notation referring to recommendations of the Track Committee.

Omit clauses (36) and (37).

Add to clause (38) notation referring to the standards of the Track Committee.

Amend clause (40) to read as follows:

"(40) Guard-rails must be so placed that the gage distance from the frog point to the flangeway side of the guard-rail shall be at least 4′ 6¾″, and the distance between flangeway sides of the wing-rail and guard-rail shall not exceed 4′ 5″."

Amend clause (41) to read as follows:

"(41) All signal posts, whistle posts, mile posts, signal targets, bridge and other standard signs must be placed so that they will not be obscured."

Amend clause (43) to read as follows:

"(43) Tools must not be left where they are liable to be struck by trains."

Amend clause (49) to read as follows:

"(49) Fences and gates along the right-of-way shall be kept in repair, and all gates kept closed when they are not in actual use, and report be made to the .....(Title).....of all gates which are habitually left open."

Amend clause (51) to read as follows:

"(51) Track jacks must not be used between the rails of main tracks, except in unavoidable cases; and then only under flag protection, as per rule 53."

Amend clause (53) to read as follows:

"(53) The track must never be obstructed without first displaying stop signals in general accord with Rule 99 of the American Railway Association. Stop signals must be in the hands of reliable men. Flagmen must stop all trains and explain to the engineman the nature of the obstruction and its exact location."

Amend clause (57) to read as follows:

"(57) Except in emergencies, no work that will obstruct the track shall be done during fogs or storms."

Amend clause (58) by substituting the words, "displayed at a proper distance" for "out a sufficient distance."

Amend clause (60) to read as follows:

"(60) Each main track shall be considered as a single-track railroad upon which trains are likely to run in either direction at any time, and signals must be displayed accordingly."

Amend clause (63) by adding after the word "sidings," "street or public crossings."

Amend clause (66) by inserting the words, "main track" before the word "switches" in the first line.

IRON AND STEEL STRUCTURES.

(For Report, see pp. 81-96; discussion, pp. 1047-1057.)

Amend clause (16) on page 88 by substituting the word "bevel" for the word "camber."

Amend clause (20) on page 88 to read as follows:

"(20) Examine and measure bored pin holes carefully to insure proper position, dimensions and spacing and smoothness of finishing."

Omit clause (23) on page 88.

Omit the word "driving" in the second paragraph of clause (28) on page 89.

Amend clause (20) by adding after the word "removed" in the second line, "which it is desired to re-erect."

TRACK.

(For Report, see pp. 97-131; discussion, pp. 1058-1068.)

Amend the typical plan following page 131 by substituting the words "bill of timber" for "bill of material."

Omit the third paragraph on page 93.

Insert "per square inch" on the first line of the table under Physical Properties and Tests.

Amend the third paragraph on page 99 to read as follows:

"The spike holes must be clean cut without burrs, and the plates must not be cracked or bent out of shape in punching the holes."

Amend the fourth paragraph to read as follows:

"All plates must be stamped on the top side outside of the rail seat with the prescribed mark."

Amend the paragraph under the heading "Shipping," on page 100, to read as follows:

"Tie-plates shall be wired together in bundles of uniform number and weight, not to exceed 100 lbs., and properly tagged."

Amend the paragraph under the heading "Shipping" on page 101 to read as follows:

"Tie-plates shall be wired together in bundles of uniform number and weight, not to exceed 100 lbs., and properly tagged.

Under the heading "Workmanship and Finish," on page 102, add the following:

"Care must be taken to avoid damage to the metal by overheating in manufacture."

Under the heading of "Workmanship and Finish," on page 105, amend the third paragraph by inserting at the beginning, "The length under the head shall not be less," etc.

Amend the paragraph under "Marking and Shipping," on page 106, by substituting the words, "shall be packed in good serviceable packages" for "kegs or bags."

Amend the seventh paragraph on page 107, under the heading "Anti-creepers," to read as follows:

"They must not loosen when in place sufficiently to render the anti-creeper inoperative when the rail slacks back."

YARDS AND TERMINALS.

(For Report, see pp. 913-954; discussion, pp. 1098-1100.)

Amend conclusion (2) on page 924 by substituting the following in the fourth line:

"It is recommended that, wherever conditions demand, baggage and express be received, delivered and handled below or above the train floor (as grade conditions permit)," etc.

Amend conclusion (4) to read as follows:

"(4) Where practicable, on station throat tracks the curvature through switches should not exceed that of a No. 8 slip on tangent."

Amend conclusion (2) on page 937 by omitting the words "safe and" in the second line.

Amend the third paragraph of conclusion (2) by substituting the word "multiple" for the word "four."

UNIFORM GENERAL CONTRACT FORMS.

(For Report, see pp. 699-709; discussion, pp. 1144-1164.)

Amend third paragraph on page 701, Agreement Form, to read as follows:

"The contractor shall furnish all materials, superintendence, labor, equipment and transportation, except as hereinafter specified, and shall execute, construct and finish, in an expeditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer of the Company," etc.

Amend clause (1), second paragraph, by omitting the words, "until the final completion and acceptance of the work."

Amend clause (15) by omitting the words "by or" in the fifth line.

Amend clause (29), first paragraph, by inserting a blank before the word "Engineer" in the third line.

Amend clause (32) by substituting a blank for the words and figures ten in the second line.

Amend the wording of the fourteenth line to read, "value of materials and fixtures furnished by the contractor on the work," etc.

First and second paragraphs on page 708 to be lettered (a) and (b), respectively.

Amend clause (36) by substituting a blank for "20th" in the last line of the second paragraph.

SIGNS, FENCES AND CROSSINGS.

(For Report, see pp. 791-830; discussion, pp. 1171-1178.)

Insert in conclusion (5) on page 816, after the word "rock," in the third line, "of low absorption."

Amend conclusion (9) by inserting after the words, "90 days," "when cured naturally."

Substitute the words "form of packing" for "concrete packing" on the plan on page 823.

WOODEN BRIDGES AND TRESTLES.

(For Report, see pp. 652-697; discussion, pp. 1136-1143.)

Amend conclusion (3) by inserting after the words "guard-rail," "when used."

Amend conclusion (4) to read, "the inside guard-rail must not be higher or over one inch lower than the running rail."

PART 2

MONOGRAPHS

LOCOMOTIVE FUEL CONSUMPTION AND THE SPEED DIAGRAM.

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LOCOMOTIVE FUEL CONSUMPTION.

The largest primary account in the operating cost of the average railroad is "Fuel for Road Locomotives." Locomotive fuel consumption can be divided as follows:

(1) Fuel used for work.

(2) Fuel used account of leakage of water and steam, and for steam used for brakes, whistling, etc.

(3) Fuel used for re-evaportion due to radiation.

(4) Fuel used at enginehouses, "firing up," etc.

The tables in the American Railway Engineering Association Manual of 1911 provide for fuel used under the first three headings during the period of maximum effort.

Two tons of coal per hour is the average that can be properly hand-fired by a single fireman in a modern freight locomotive, through the long periods of maintained effort required in making the schedule with the maximum train. The tables referred to, however, provide for any practical amount of fuel consumption, but it is rare, even with a relief fireman, that over five thousand pounds of coal will be fired during the period of maximum work by a freight locomotive.

No accurate mathematical method can be fixed for estimating locomotive fuel consumption. Details of construction, condition of the locomotive and the "personal equation" of both the engineer and fireman introduce variables which materially affect the question. Single tests may show what might be expected under like conditions, but for the student of economics in railway location or operation, averages must be considered. The personal equation of the fireman probably is the greatest variable, and for the same man will vary widely on different trips.

No economic study can be of value that does not consider the average efficiency of the laborer.

The fuel used by locomotives while drifting or at rest is a material amount of the total consumption. At the 1904 convention of the American Master Mechanics' Association, some valuable data was presented covering

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twenty-one tests over an engine district on the Atchison, Topeka & Santa & Fe Railway and twenty-four tests on the Norfolk & Western Railway. From this data the accompanying tables, covering fuel used at rest, were obtained. The tables are arranged in the order of delayed time for each locomotive, and a study of the coal used as compared with the time delayed will show the variable character of the personal equation and the necessity of following the rule of averages in estimating economies.

ATCHISON, TOPEKA & SANTA FE TEST TRAINS.

TEST TRIP, 112.84 MILES. COAL, 11,000 B. T. U.

Locomotive No.	Square Feet H. S.	Delays Hrs.-Min.	Used at Delays	
			Lbs. Coal	Lbs. Water
606	2626	1 : 17	735	1865
606	2626	1 : 20	377	3000
606	2626	1 : 52	1086	1487
606	2626	3 : 05	1800	1991
606	2626	3 : 52	1186	1159
601	2626	2 : 08	585	2053
601	2626	2 : 44	1110	2525
601	2626	3 : 42	1290	2458
601	2626	3 : 55	1260	3981
601	2626	5 : 42	1590	1604
1051	3738	1 : 03	615	1195
1051	3738	1 : 05	660	3767
1051	3738	1 : 11	1020	1393
1051	3738	1 : 35	770	1758
1051	3738	3 : 25	1255	1254
565	3666	3 : 15	1155	2293
175	1560	1 : 06	490	1027
175	1560	1 : 17	260	1022
175	1560	2 : 25	980	731
175	1560	2 : 44	610	889
175	1560	3 : 19	650	2031
Totals.....	56416	52 : 02	19484	39483

Average heating surface per test trip.....2,686 sq. ft.
Coal used per hour delay—Total.....374.5 lbs.
Per 1,000 ft. H. S.....139.4 lbs.
Water used per hour delay—Total.....758.8 lbs.
Per 1,000 ft. H. S.....282 lbs.
Coal used per trip "firing up" at enginehouses, average of 15 tests.. .....515 lbs. per 1,000 sq. ft. H. S.

The fuel loss by radiation depends on the temperature of outside atmosphere, area of boiler exposed and quantity and quality of boiler covering. The exposed area varies and is not one of the items given with locomotive dimensions. With modern locomotives there is from 4.75 to 5.75 sq. ft. of exposed area to one square foot of heating surface. The proportion of this outside area insulated against transmission of heat varies. Evaporation is from heating surface, and, owing to the variables and un-

determined area of boilers exposed, the losses will be based on heating surface.

The heat loss from radiation is the total loss when locomotive is not working, less the loss due to leakage and use of steam and water for other purpose than work.

In the Atchison, Topeka & Santa Fe tests, it would require 34.7 lbs. of 11,000 B. T. U. coal per 1,000 sq. ft. of H. S. to evaporate the 282 lbs. of water used per hour idle from a feed water temperature of 65 degrees to a boiler pressure of 200 lbs.

NORFOLK & WESTERN TEST TRAINS.

TEST TRIP, 99.7 MILES. COAL, 14,000 B. T. U.

Locomotive No.	Square Feet H. S.	Delays Hrs.—Min.	Coal Used at Delays
923	2474	1 : 43	1400
923	2474	2 : 36	500
923	2474	2 : 36	925
923	2474	2 : 40	1800
923	2474	4 : 14	800
923	2474	4 : 38	1000
923	2474	5 : 20	700
923	2474	6 : 23	2000
923	2474	8 : 37	600
923	2474	8 : 48	2300
923	2474	10 : 23	1838
923	2474	12 : 42	3800
839	2415	1 : 39	1175
839	2415	1 : 55	300
839	2415	2 : 15	400
839	2415	2 : 23	500
839	2415	2 : 44	900
839	2415	3 : 20	300
839	2415	3 : 53	800
839	2415	4 : 41	600
839	2415	5 : 00	1000
839	2415	5 : 41	1000
839	2415	5 : 47	900
839	2415	6 : 00	1300
Totals.....	58668	115 : 48	26838

Average heating surface per test trip.....2,445 sq. ft.
Coal used per hour delay—Total.....232 lbs.
Per 1,000 ft. H. S..... 94.8 lbs.
Coal used per trip "firing up" at enginehouses; average, 24 tests..
.....501 lbs. per 1,000 sq. ft. H. S.

The Norfolk & Western tests do not give the water and steam losses while at rest. In ninety-seven tests at the St. Louis Exposition testing plant, the average steam loss per hour per 1,000 sq. ft. of heating surface was 151 lbs. These locomotives were probably in as good or better condition than the average road locomotive and the Norfolk & Western

locomotives can be considered as losing at least this amount of water and steam. There would be required 14.6 lbs. of 14,000 B. T. U. coal per 1,000 sq. ft. H. S. to evaporate this quantity of water wasted.

A fair average for this loss of heat due to other uses of steam and leakage can be based on 200 lbs. loss an hour per 1,000 sq. ft. of heating surface.

The coal loss from radiation during delays in these tests can then be estimated as follows:

Atchison, Topeka & Santa Fe: 139.4—34.7=104.7 lbs. per 1,000 ft. H. S.

Norfolk & Western: 94.8—14.6=80.2 lbs. per 1,000 ft. H. S.

Mr. Henderson, in "Locomotive Operation," states that in tests with one locomotive he found the loss from radiation at 28 M. P. H. velocity double the loss with locomotive standing.

Practically all drifting is done on gradients, and at a velocity exceeding this, therefore no great error will occur in basing this loss while drifting at double the amount standing.

The fuel used in the tests at enginehouses firing up does not seem consistent with the total heat units when comparing the two series of tests. This is due to many causes. Enginehouse practice varies widely on different roads and in the houses of the same road. Probably the least study in reduction of fuel wastes is given to fuel used while engine is housed.

The following table is arranged based on results secured in these tests and the assumption that evaporation is proportional to the total heat units in the coal, except in the case of coal "firing up," which, until better methods obtain, is based on amount actually used in the tests. In proportioning the fuel on the B. T. U. contained, the fact that ash and other components of the fuel vary must be neglected along with the other variables.

APPROXIMATE POUNDS COAL BURNED PER 1,000 SQ. FT. HEATING SURFACE—LOCOMOTIVE NOT WORKING.

B. T. U. Per Pound Coal	Per Trip Firing Up	Radiation, Leakage, etc.—Per hour	
		Standing	Drifting
10000	520	145	263
11000	515	132	239
12000	510	121	219
13000	505	111	202
14000	500	103	188
15000	495	97	175

As a test of the value of the above table in approximating fuel consumption, the following data is given covering one week's actual operation on a division of three engine districts. The data given is actual, except

that time drifting is estimated by platting a "time diagram," and this deducted from actual running time to get time "working."

Total freight locomotive miles		27,575
Total freight locomotive trips		220
Heating surface per locomotive		2,905
Hours delay (standing)		855.4
Hours drifting	408.2	
Hours working	1,312.6	
Total hours running time		1,720.8

Average value of coal, 11,000 B. T. U.

ESTIMATED FUEL USED.

	Pounds.
Firing up: 220 trips at 1,496 lbs	329,120
Standing: 855.4 hours at 383.46 lbs	328,012
Drifting: 408.2 hours at 694.3 lbs	283,413
Working: 1,312.6 hours at 4,000 lbs	5,250,400
Total estimate	6,190,945
Estimate per freight locomotive mile	224.5 lbs.

The actual coal used per freight locomotive mile on this division during the month from which this data was taken was 224.1 lbs. It cannot be expected that as close an approximation can be obtained in all cases, but this method can be applied to different locations or different divisions and a reasonable comparison made of the relative fuel economy, providing the data to estimate the same is at hand.

The table covering the fuel used is of little value except as information to the student of economics unless a method be provided for estimating the various components of the total time over a district. From data secured on two western roads, single-track divisions, and covering two weeks' time on seven engine districts of one line and one week's time on three-engine districts of the other, the average time taken for orders, coaling and watering locomotives was one-half minute per engine per mile of district. The total number of meeting points and points of passing by superior trains was 8,709, and the average time delay for each freight train was 15.9 minutes for each of such points. On the lighter traffic districts, where time was ample, more time was taken than above at meeting or passing points.

A safe figure for estimating the delay time is one-half minute per engine mile plus 15 minutes for each train met or train in same direction allowed to pass.

The number of such points can be closely approximated by estimating the number of trains required to handle a given traffic, both freight and passenger, and platting the same graphically on a chart similar to those used in making time cards. One side drawn to scale of miles over locomotive district; the other into scale of 24 hours. Where information

is not available as to the time trains may reach the district, the total number of trains may be spaced out through the 24 hours. The trains in one direction may be platted in straight lines, covering the district in the time of the *desired* schedule. The passenger trains and one freight train in the opposite direction may then be platted and the intersections of the one freight with other trains counted.

With this method, lines representing schedules for the different classes of freight service may be used and the points determined for each class.

The foregoing method refers to single track. On double track only trains in the direction of traffic should be considered.

Running time, divided between time working and drifting, may be estimated by the construction of a time diagram.

The method requires labor, but after preparing the tables suitable for the problems it is possible to plat the speed lines and calculate the time over fifty miles or more of profile per day. A problem in economics of railway operation or location is not solved until reasonable proof has been obtained that the assumed train can move over the district within the allotted time, and on a district with adverse grade, most of which may be controlling and practically all in one direction, or on districts of a very low rate of gradient, the locomotive must be operating at a shortened cut-off to get over the district without overtime. The time taken in the preparation of a set of tables is well spent, and the tables are valuable for many different problems. The time diagram will frequently save the engineer severe criticism, and, of far greater importance, will save the railways money in preventing expenditures for improvements that are based on incorrect assumptions.

THE SPEED DIAGRAM AND ITS USES.

The preparation of the data necessary to construct a speed diagram requires, first, that a given locomotive be considered, preferably of modern type, and of good power; second, total weight per car of train be approximately known.

For the purpose of illustrating the methods used in the preparation of data, the following locomotive is considered:

Type, 2—8—0.
Cylinders, 22 in.x30 in.
Drivers, 63 in.
Heating surface, 3,300 sq. ft.
Boiler pressure, 200 lbs.
Weight (including tender), 173 tons.

Using the methods outlined by the 1911 Manual of the American Railway Engineering Association, and considering 4,000 lbs. of coal with thermal value of 11,000 B. T. U. as the maximum per hour for maintained effort, this locomotive can supply steam for full cut-off up to a velocity of 5 miles per hour, with a cylinder tractive power at this velocity

of 39,000 lbs. The locomotive resistance, excluding head end resistance, will be 2,360 lbs.

This locomotive is a fair average of the modern consolidation type used on nearly all roads of any considerable traffic, and the calculated maximum velocity at full cut-off is very close to what is being obtained with simple engines in the large territory in which the available fuel approximates a thermal value of 11,000 B. T. U. per pound. This locomotive burning a higher grade fuel would be able to generate steam to fill the cylinders at full cut-off at a greater velocity than given, and the calculations necessary for a speed diagram would produce different results from the tables presented with this paper, but the methods involved in the calculations would be the same.

Variables enter into the question of train resistance, as a careful reading of the text of the Economics Committee report in Part 1, Vol. 12, of the American Railway Engineering Association Proceedings will disclose, and as any engineer can testify who has tried to analyze dynamometer records of two districts of widely different character, with reference to curvature and character of maintenance of both roadway and equipment. The modern formulæ generally adopted for practical purposes consider the resistance per car on level grade as A+B T, in which A and B are constants and T is tons weight of car and contents. The formula given in the 1911 Manual is a compromise between resistance as found on lines of short tangents, large percentage of curvature and gondola cars and that found on lines of very moderate curvature with the bulk of trains composed of box cars. It is probably too high for prairie lines of fair maintenance, as a careful analysis of twelve test trains, maintaining uniform speed for considerable distances on tangent and uniform grade, shows an average of several readings not varying far from the formula of "R" per car=86+2.6 T for level grades. No criticism is intended of the formula adopted by the Association, the present idea being to show the variable character of resistance, and that the formula as adopted may be high for some cases and low in others. The running time of a maximum train of empties between the terminals of a district is necessarily greater than required for a train of maximum loads. The reason for this can readily be understood by considering the difference in resistance due to grades for both trains. Any formula that considers the loading of cars will illustrate the point, but in the following the American Railway Engineering Association formula is used.

Weight of car	20 tons	70 tons
Resistance 1 per cent. grade	565.6 lbs.	1,675.6 lbs.
Resistance level grade	165.6 lbs.	275.6 lbs.
Per cent. "R" on level	29.3 per cent.	16.5 per cent.

Briefly stated, the proportional resistance on the flatter grades for light loads is much greater than for heavier loading, and on these flatter grades the train with the concentrated loading can accelerate to and maintain a higher velocity.

The average running time can be estimated by using a figure for resistance that will approximately agree with the average weight per car of train. In the following calculations 5.4 lbs. per ton level resistance is assumed. This would represent an average weight per car of 30.7 tons according to the formula R=86+2.6 T; 32 tons by the Pennsylvania formula, and 38 tons by the American Railway Engineering Association. The average weight per car of the leading roads of the country varies between 30 and 40 tons.

Tables Nos. 1 to 5 were originally constructed for use on districts having ruling grades from 0.7 per cent. to 1 per cent., although they may be used with a considerable degree of accuracy for lighter gradients. The method of using them will be explained later.

Table No. 1, "Locomotive loaded with maximum train for 1 per cent. grade," is figured on the maximum at 5 M. P. H. Formerly, in calculations of this character, 10 M. P. H. was the minimum velocity assumed, but common practice in everyday work for dead freight will load the locomotive down to this low velocity on the ruling grades wherever there is sufficient amount of lighter gradients on the district so that the train can cover the same without overtime, unless the traffic be so dense as to call for the stopping and starting of trains on the ruling gradients, due to block signals being against them.

This table gives the drawbar power of locomotive from starting up to 35 M. P. H. on level grade, the train resistance, and the difference between the two. This difference in resistance represents the power that can be used in accelerating, or retarding trains on level grade, or in overcoming gradient, as explained in the notes on the table.

Tables Nos. 2 and 3, covering distances in stations and decimals passed in accelerating or retarding with locomotive working, are calculated from the formula given on table No. 1. The distances given for acceleration to each velocity being the sum of the various increments in accelerating, from mile to mile, velocities from the starting point; or, in case of the heavier grades, from the lowest mile velocity at which train can be moved. In retarding grades the distances are from an initial velocity of 35 M. P. H. The distance passed over in going from one velocity to another is the difference between the figures shown on the table for the respective velocities.

Table No. 4, covering distances traveled in drifting, is calculated on the same principle, except that the resistance of train, locomotive resistance and the mean head end resistance are added together, and divided by total weight of train, including locomotive to get resistance per ton of train. The difference between this and grade resistance gives the power per ton for accelerating or retarding train. The use of the mean head end resistance, while not mathematically correct, creates only a slight error in the tables, as it is only a small part of the resistance, and it simplifies the preparation of the table materially.

Platting the speed line closely for any given profile will show that the line for any one gradient advances in a very flat curve except at

starting. For all practical purposes, the line can be assumed as advancing in a straight line throughout the length of a single stretch of gradient, or to the point where speed becomes a maintained velocity, this method increasing slightly the total estimated time. The speed can be estimated from the tables to the nearest tenth of a mile per hour for the end of each stretch of gradient. For intermediate rates of grade not shown on the table, the values can be determined by interpolation. The speed diagram should be marked plainly, showing points where drifting begins or ends. As a general proposition, where there is ample time for schedule of train between terminals, the locomotive should be considered as drifting on all the accelerating gradients where the distance in accelerating to the maximum safe velocity is not too great. In these tables 35 M. P. H. has been taken as the average maximum safe speed for freight trains. The application of brakes at stops should be considered as time drifting, and frequently the arrangement of grades approaching stops is such that the locomotive can be considered as drifting and retarding with possibly a short final application of brakes. If at any portion of the line the locomotive would require less than its full power to keep the train at its maximum safe velocity or at a fixed rate of speed, for the purpose of estimating, the locomotive should be considered as working at full power for a distance and then drifting so as to produce as nearly the average rate as practicable. In calculating total time working or drifting, the total area lying between the speed and base lines can be estimated for each, the mean velocity for each obtained and, with distance known, the time for each calculated. A second method is to calculate the time for each stretch of grade to the nearest hundredth part of a minute, using the mean speed as a divisor. In this method a table of feet per minute for miles and tenths of miles per hour is a convenience, particularly where slide rule is used.

Table No. 5, giving grades on which various weight trains can accelerate to and maintain the given velocities, is calculated, using the same locomotive and train resistance per ton as for the other tables. The difference between the locomotive draw bar pull at given velocity and train resistance on level grade for the given train divided by the tons weight of train, including locomotive, gives the grade resistance for the gradient on which the given velocity can be maintained. The formula can be expressed as follows: P=Draw bar pull, level grade; R=Resistance (train), level grade; T=Tons train, including locomotive; G=Per cent. gradient for maintained velocity at given speed. Then

$$G = \frac{P - R}{20T}$$

The speed diagram platted, and both the time and distance calculated divided between locomotive working and locomotive drifting covers only the train for which the tables were calculated. The next step is to determine approximately what time would be required for other weight trains of the same average loading per car. With reference to trains drifting, the

time and distance in accelerating or retarding between two given velocities is directly proportional to the net accelerating or retarding forces per ton. The resistance per ton for the 1,479-ton train used in the tables is 6.427 lbs., while drifting and the "Grade of Repose," on which velocity would neither increase nor decrease, is practically 0.32 per cent. Considering two other trains with the same locomotive and train resistance (5.4 lbs.) per ton, one 873 tons gross, including locomotive, and the other 3,173 tons gross, the following gives a comparison of the time and distance in accelerating on descending 1 per cent. and 0.4 per cent. gradients:

Gross weight train	1,479 tons	873 tons	3,173 tons
Resistance per ton drifting	6.427 lbs.	7.14 lbs.	5.88 lbs.
Grade of repose	0.321 per cent.	0.357 per cent.	0.294 per cent.
Accelerating force, 1 per cent.	13.573 lbs.	12.86 lbs.	14.12 lbs.
0.4 per cent.	1.573 lbs.	0.86 lb.	2.12 lbs.
Distance 5 to 35 M P. H.,			
1 per cent.	6,183 ft.	6,539 ft.	5,949 ft.
0.4 per cent.	53,415 ft.	97,674 ft.	39,623 ft.
Time 5 to 35 M. P. H.,			
1 per cent.	4.01 min.	4.24 min.	3.86 min.
0.4 per cent.	34.67 min.	63.39 min.	25.72 min.

The above shows that the lighter train takes a greater distance and more time to accelerate between two given speeds, and in the case of the 0.4 per cent. grade the difference is very marked, and that in accelerating the same distance as the 1,479-ton train the final velocity would be less for the 873-ton train and would be reached earlier by the 3,173-ton train. All trains of a district will have the same distance and grades to pass over. The following shows the time drifting the same distance with an initial velocity of 5 M. P. H. for widely different trains on heavy and light gradients:

Grade	1 per cent.			0.4 per cent.		
Distance	6,183 ft.			53,415 ft.		
Gross tons train	1,479	873	3,173	1,479	873	3,173
Minutes, time	4.01	4.10	3.94	34.67	46.51	30.20
Final velocity, M. P. H.	35	34.25	35	35	26.1	35

The above is from a theoretical standpoint, and in practical operation the trains on the flatter grade would be accelerated by locomotive working to some velocity approaching the safe maximum rather than waste time drifting ten miles or more to reach that velocity. The difference in time drifting is very rapidly dispelled as grade increases above 0.4 per cent.; therefore, for all practical purposes, trains of different weights and average loading per car can be assumed as drifting the same distance and in the same time.

The time working locomotive will vary widely, and the method of approximately this time for various weights of trains of average car loading can be best explained by taking an example for illustration. Con-

sider a speed diagram for the tabular train platted over the following distance with the given results:

Length of district	120 miles
Controlling gradient	0.6 per cent.
Maximum tons cars and loading at 5 M. P. H. velocity on controlling grade (average car loading)	1,986 tons
Time drifting with diagram train	2 hours
Time working with diagram train	5 hours
Distance working	90 miles

The average velocity of the train while locomotive is working is 18 miles per hour. From table 5 we find the 1,306-ton train back of locomotive can maintain a velocity of 18 miles per hour on 0.27 gradient. A table can now be prepared for the district from table 5, showing the velocities and time for trains of other weight moving in the same direction. The 0.27 per cent. gradient is the approximate average gradient considered for all the trains, and with the velocities for the different trains on this gradient taken from table 5, the time locomotive is working can be calculated for each. An example of such a table is presented, including a train in excess of the maximum that can be hauled over the controlling grades.

Cars and Load, Tons	Vel. on 0.27%	Hours Running Time			On 0.6% Grade	
		Working	Drifting	Total	D. B. Pull	Veloc.
700	27.0	3.33	2.0	5.33	12180	18.81
800	25.0	3.60	2.0	5.60	13920	17.00
900	23.33	3.86	2.0	5.86	15660	15.38
1000	21.67	4.14	2.0	6.14	17400	13.89
1100	20.33	4.43	2.0	6.43	19140	12.51
1200	19.14	4.70	2.0	6.70	20880	11.20
1306	18.0	5.00	2.0	7.00	22724	9.92
1400	17.0	5.29	2.0	7.29	24360	8.94
1500	16.0	5.63	2.0	7.63	26100	8.04
1600	15.0	6.00	2.0	8.00	27840	7.28
1700	14.0	6.43	2.0	8.43	29580	6.61
1900	12.33	7.30	2.0	9.30	33060	5.45
2100	10.67	8.44	2.0	10.44	36540	....

From this table the running time for the maximum train with draw bar pull of 34,556 can be interpolated and will be found to be 9.79 hours total. The running time for any train with the average car loading or the tons of train for any desired schedule can be found by interpolation from the table. A very convenient form to put this is to plat it graphically, with running time to scale on one side of chart and either the speed in M. P. H. on controlling grades, or drawbar pull for given locomotive, on the other. This is of particular value in making rating sheets for a given schedule over a district and, with velocity in miles per hour on controlling grades, is available for any locomotive that makes steam for full cut-off at about the same velocity as the assumed locomotive. Assuming that the traffic each way per day is twelve trains, divided equally

between passenger, time freight and dead freight spaced alternately two hours apart at beginning of runs, with schedules over district of 4 hours for passenger, 10 hours for time freight and 12 hours for dead freight, the probable number of delay points for freights would be ten for time and eleven for dead freight.

The total schedule would be as follows:

	Time freight	Dead freight
Water, coal, orders, etc.	1 hour	1 hour
Meeting and passing points	2.5 hours	2.75 hours
Drifting	2 hours	2 hours
Working	4.5 hours	6.25 hours
Total schedule	10 hours	12 hours
Weight cars and contents (average loading)	1,426 tons	1,658 tons
D. B. pull, maximum grade	19,592 lbs.	28,849 lbs.

The weight is interpolated from the table. With this data it is possible to estimate the fuel per engine-mile or ton-mile for the above trains, but to get the average used it is necessary to work up the data for trains in both directions. The time calculated for the tabular train, the tables can be used in many ways for approximations.

Take the 1,658-ton train just used in the preceding example. It is desired to know the approximate tons of train of light loading of cars that can be handled over the district in the same time. The mean drawbar pull of the 1,658-ton freight on the average 0.27 per cent. grade would be 17,906 lbs. If the lighter loading is such as to produce a drawbar pull of 8 lbs. per ton on the level, on the average grade of 0.27 per cent. it would be 13.4 lbs. and 1,336 tons would be the approximate weight of the lighter loaded train that could be handled in the same time with a drawbar pull of 23,246 lbs. on the controlling grade. This train would make faster time on grades in excess of the average and slower time on the lighter grades, the drawbar pull being less than for the 1,658-ton train for the heavier gradient, and greater as the grade decreases below the average.

Taking the same resistance of 8 lbs. per ton for level grades, it is desired to find the additional time it will take to handle a train with the same drawbar pull on the controlling grade as the 1,658-ton train. The drawbar pull on 0.6 per cent. grade is 28,849 lbs., and the train of lighter car loading would weigh approximately 1,442 tons, cars and contents, or 1,615 tons gross. Take the formula $G = \frac{P-R}{20T}$; then $P = 20\ TG + R$. Substituting the values, tons of train $T = 1{,}615$; grade $G = 0.27$; train resistance on level $R = 11{,}536$; the drawbar pull on the level or $P = 20{,}257$. Table No. 1 shows this locomotive drawbar pull at 13.26 M. P. H. To cover the 90 miles working would require 6.78 hours, or 32 minutes longer than the 1,658-ton train, and in this particular case would prob-

ably require the payment of one hour overtime to the engine and train crews, according to the usual pay schedule, providing that all time in excess of 10 M. P. H. over a district be paid for with overtime calculated for each trip to the nearest even hour.

The use of the speed diagram will show the fallacy of considering rise and fall of the same amount of equal values. The values for the same amount will vary with the gradients, speed of approach and location. As a general proposition, with the same character and loading of a train, and where runs of 15 miles or more can be made without stop, the time over two districts of the same rise and fall will be practically the same, but the fuel consumption on the district of lighter grade will be less.

The use of the speed diagram will solve the problems of fuel and water accounts, and, with schedules of pay of engine and trainmen at hand, the main problems of "Conducting Transportation" most affected by the physical characteristics of locations can be solved. A word of caution may be well at this point. Do not use the tables herewith unless they fit the local conditions as to fuel and resistance. Where these differ materially, make up a set of tables on the same principles for best results. In platting speed line, make all necessary stops for fuel, water, railway crossings, etc., and a sufficient number of other points to cover meeting and passing of trains.

The method herein described requires work and time, but it does away with the more or less "scientific guesswork" with reference to the effect of distance, gradient, rise and fall, and curvature on the main accounts under "Conducting Transportation" expenses. There will be less disappointment in the expectation of producing a decreased train mileage directly in proportion to the decreased total resistance of trains on the controlling gradients. The actual economies realized will be much nearer the estimated economies than the average guesswork. The most important value is that it will, in many cases, save the waste of money in the investment of so-called improvements which fail to realize a fair return on their cost.

The value of the method does not end with the Engineer's estimate of relative economies of different routes, but, with the data for a district once worked out, many of the important problems of movement of traffic can be solved with sufficient accuracy to place the calculated results in practice, and, with possibly a few slight changes found necessary in practice, render greater efficiency in operation. The value of additional main tracks can be estimated logically, so that an executive official without technical education can understand the methods of reasoning, even though he may not know the mathematical methods which determined the running time. The time spent in preparing the tables and in making the calculations for any given lines is in itself a foundation for greater economies, and the cost of this time will bring abundant results.

Cars and Contents, 1306 Tons.
Locomotive, 173 Tons.
Train Resistance, 5.4 Lbs. Per Ton for Velocity 4 Miles to 35 Miles Per Hour.

Table No. 1

Locomotive loaded with maximum train it can haul on 1 per cent. grade at 5 miles per hour maintained speed.

Velocity, Miles Per Hour	Level Grade			
	Drawbar Pull "P"	Train Resistance "R"	P—R Pounds	P—R Per Ton
Start	38980	16978	22002	14.88
1	38512	11754	26758	18.09
2	38043	9142	28901	19.54
3	37574	7836	29738	20.11
4	37104	7052	30052	20.32
5	36634	7052	29582	20.00
6	33328	7052	26276	17.77
7	30567	7052	23515	15.90
8	28259	7052	21207	14.34
9	26324	7052	19272	13.03
10	24669	7052	17617	11.91
11	23221	7052	16169	10.93
12	21870	7052	14818	10.02
13	20577	7052	13525	9.14
14	19345	7052	12293	8.31
15	18168	7052	11116	7.52
16	17041	7052	9989	6.75
17	15992	7052	8940	6.04
18	14985	7052	7933	5.36
19	14082	7052	7030	4.75
20	13179	7052	6127	4.14
21	12334	7052	5282	3.57
22	11561	7052	4509	3.05
23	10869	7052	3817	2.58
24	10197	7052	3145	2.13
25	9617	7052	2565	1.73
26	9074	7052	2022	1.37
27	8565	7052	1513	1.02
28	8103	7052	1051	.71
29	7687	7052	635	.43
30	7298	7052	246	.17
30.67	7052	7052	0	0
31	6932	7052	—120	—.08
32	6584	7052	—468	—.32
33	6256	7052	—796	—.54
34	5954	7052	—1098	—.74
35	5672	7052	—1380	—.93

P=Drawbar pull of locomotive in lbs.
R=Train resistance in lbs.
V_1=Terminal velocity in miles per hour.
V_2=Initial velocity in miles per hour.

(P—R) per ton of train (including locomotive) when positive in value is the net power available for use in overcoming grade resistance at maintained speed. Also represents the power available for acceleration.

(P—R) per ton of train (including locomotive) when negative is the assistance that must be received from descending grades in order to maintain the given velocity. When such assistance is not received it becomes a retarding resistance.

For (P—R) for other than level grades subtract from its value per ton of train for level grades the grade resistance in pounds per ton of train.

The distance in feet required to accelerate from a given velocity to another equals $70 (V_1^2 — V_2^2)$ divided by the mean of (P—R) per ton of train for the two velocities.

Weight Cars and Lading.....1306 Tons
Weight Locomotive..... 173 "
Total Train.....1479 "

Table No. 2
ACCELERATIONS AND RETARDATIONS
ENGINE WORKING STEAM—ASCENDING GRADES

Locomotive loaded with maximum train it can handle on 1 per cent. grade at 5 miles per hour maintained speed.

Velocity Miles per Hour	0.0 Grade	+0.1 Grade	+0.2 Grade	+0.3 Grade	+0.4 Grade	+0.5 Grade	+0.6 Grade	+0.7 Grade	+0.8 Grade	+0.9 Grade	+1.0 Grade
0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1	.04	.05	.06	.07	.08	.11	.16	.29	Will not start	Will not start	.....
2	.15	.18	.20	.23	.28	.35	.47	.73	.74	2.56	.....
3	.33	.39	.43	.50	.60	.71	.92	1.33	1.66	4.48	Will not start
4	.59	.67	.75	.87	1.03	1.19	1.52	2.12	2.82	6.70	23.33
5	.92	1.02	1.16	1.34	1.58	1.81	2.29	3.14	4.33	9.61	62.70
6	1.33	1.48	1.68	1.94	2.29	2.68	3.41	4.72	7.00	5.9 16.48 / 78.32	62.93
7	1.87	2.09	2.39	2.78	3.32	4.01	5.29	7.94	6.9 16.18 / 104.81	71.08	56.05
8	2.56	2.89	3.33	3.93	4.79	6.06	8.66	17.32	85.35	63.30	53.18
9	3.43	3.91	4.56	5.48	6.89	9.29	15.74	8.3 37.46 / 95.04	73.42	59.65	51.03
10	4.50	5.18	6.13	7.53	9.87	14.67	9.9 38.86 / 157.48	89.33	68.29	56.90	49.15
11	5.79	6.74	8.11	10.31	14.17	25.02	126.52	80.64	64.52	54.49	47.38
12	7.33	8.64	10.60	13.91	20.69	58.91	101.18	74.94	61.31	52.26	45.67
13	9.16	10.95	13.74	18.80	31.77	161.06	90.66	70.38	58.40	50.12	43.98
14	11.33	13.76	17.74	25.75	57.84	119.39	83.43	66.42	55.67	48.04	42.30
15	13.89	17.19	22.93	36.35	14.4 71.79 / 231.37	104.62	77.67	62.84	53.07	46.00	40.62
16	16.93	21.42	29.86	55.55	151.71	94.88	72.70	59.50	50.56	43.99	38.94
17	20.54	26.67	39.49	113.30	126.62	87.32	68.24	56.34	48.11	41.99	37.25
18	24.84	33.29	53.90	17.1 119.35 / 239.26	112.18	80.90	64.11	53.30	45.70	40.00	35.55
19	29.96	41.77	78.45	170.16	101.53	75.20	60.22	50.35	43.31	38.01	33.84
20	36.11	52.96	139.80	142.75	92.74	69.96	56.49	47.45	40.94	36.01	32.11
21	43.56	68.47	20.2 220.20 / 328.81	125.25	85.07	65.05	52.88	44.59	38.58	34.00	30.36
22	52.65	91.45	221.50	111.90	78.15	60.43	49.36	41.76	36.22	31.97	28.58
23	63.82	129.86	177.86	100.71	71.73	55.93	45.90	38.94	33.85	29.92	26.78
24	77.82	222.54	151.08	90.80	65.65	51.54	42.47	36.12	31.46	27.84	24.95
25	95.59	24.3 378.60 / 486.21	131.14	81.79	59.83	47.24	39.06	33.29	29.05	25.74	23.09
26	118.62	307.27	114.57	73.36	54.18	42.99	35.65	30.45	26.61	23.61	21.19
27	149.54	227.94	100.00	65.34	48.65	38.76	32.23	27.58	24.14	21.44	19.26
28	194.05	181.56	86.75	57.61	43.19	34.54	28.79	24.68	21.63	19.23	17.29
29	264.05	147.64	74.47	50.11	37.79	30.32	25.33	21.75	19.08	16.98	15.28
30	401.75	119.74	62.84	42.76	32.42	26.08	21.84	18.78	16.49	14.69	13.23
31	30.7 751.64 / 786.65	95.45	51.68	35.50	27.05	21.82	18.31	15.77	13.86	12.36	11.14
32	457.43	73.61	40.88	28.33	21.68	17.53	14.74	12.71	11.18	9.98	9.00
33	236.93	53.36	30.38	21.22	16.30	13.21	11.13	9.61	8.46	7.56	6.82
34	131.12	34.84	20.11	14.14	10.90	8.85	7.47	6.46	5.69	5.09	4.59
35	57.84	17.07	10.00	7.07	5.47	4.45	3.76	3.26	2.87	2.57	2.32

Weight Cars and Lading.....1306 Tons
Weight Locomotive..... 173 "
Total Train.....1479 "

Table No. 3
ACCELERATIONS

Locomotive loaded with maximum train it can handle on 1 per cent. grade at 5 miles per hour maintained speed.

LOCOMOTIVE WORKING STEAM—DESCENDING GRADES

Velocity Miles per Hour	0.0 Grade	—0.1 Grade	—0.2 Grade	—0.3 Grade	—0.4 Grade	—0.5 Grade	—0.6 Grade	—0.7 Grade	—0.8 Grade	—0.9 Grade	—1.0 Grade
0											
1	.04	.04	.03	.03	.03	.03	.02	.02	.02	.02	.02
2	.15	.14	.12	.12	.11	.10	.09	.08	.08	.08	.07
3	.33	.31	.28	.26	.24	.22	.20	.19	.18	.17	.16
4	.59	.54	.49	.45	.42	.39	.36	.34	.32	.30	.28
5	.92	.83	.76	.70	.65	.60	.56	.53	.50	.47	.45
6	1.33	1.20	1.10	1.01	.94	.87	.81	.76	.72	.68	.65
7	1.87	1.68	1.54	1.41	1.31	1.21	1.13	1.06	1.00	.94	.90
8	2.56	2.29	2.09	1.90	1.76	1.63	1.52	1.42	1.34	1.26	1.20
9	3.43	3.05	2.76	2.50	2.31	2.13	1.98	1.85	1.74	1.63	1.55
10	4.50	3.97	3.57	3.22	2.96	2.72	2.52	2.35	2.21	2.07	1.96
11	5.79	5.07	4.52	4.06	3.72	3.41	3.15	2.93	2.75	2.57	2.43
12	7.33	6.36	5.63	5.04	4.59	4.20	3.87	3.59	3.36	3.13	2.96
13	9.16	7.87	6.92	6.16	5.59	5.09	4.68	4.33	4.04	3.76	3.55
14	11.33	9.63	8.41	7.44	6.73	6.10	5.59	5.16	4.80	4.46	4.21
15	13.89	11.68	10.11	8.90	8.01	7.23	6.61	6.09	5.65	5.24	4.94
16	16.93	14.06	12.06	10.55	9.44	8.50	7.75	7.12	6.59	6.10	5.74
17	20.54	16.81	14.28	12.41	11.04	9.91	9.01	8.25	7.62	7.05	6.62
18	24.84	19.99	16.81	14.50	12.82	11.47	10.40	9.49	8.75	8.08	7.57
19	29.96	23.66	19.67	16.84	14.80	13.19	11.92	10.85	9.98	9.20	8.60
20	36.11	27.90	22.90	19.45	16.99	15.08	13.58	12.33	11.32	10.41	9.71
21	43.56	32.81	26.56	22.36	19.41	17.15	15.39	13.94	12.77	11.72	10.91
22	52.65	38.48	30.68	25.59	22.07	19.41	17.36	15.68	14.33	13.13	12.20
23	63.82	45.02	35.30	29.16	24.98	21.87	19.49	17.55	16.00	14.64	13.58
24	77.82	52.58	40.48	33.10	28.15	24.53	21.78	19.56	17.79	16.25	15.05
25	95.59	61.31	46.26	37.43	31.60	27.40	24.24	21.71	19.70	17.97	16.61
26	118.62	71.37	52.69	42.16	35.33	30.49	26.87	24.00	21.73	19.79	18.26
27	149.54	82.96	59.82	47.31	39.36	33.80	29.68	26.44	23.89	21.72	20.01
28	194.05	96.40	67.73	52.91	43.70	37.34	32.67	29.03	26.17	23.76	21.85
29	264.05	111.93	76.46	58.98	48.36	41.12	35.84	31.77	28.58	25.91	23.79
30	401.75	129.89	86.06	65.53	53.34	45.13	39.20	34.66	31.11	28.17	25.82
31	$30.7\frac{751.64}{786.65}$	150.77	96.62	72.59	58.65	49.38	42.75	37.70	33.77	30.54	27.95
32	457.43	175.27	108.23	80.19	64.30	53.88	46.49	40.89	36.56	33.02	30.17
33	236.93	204.25	120.98	88.36	70.31	58.63	50.42	44.24	39.48	35.61	32.49
34	131.12	238.74	134.94	97.11	76.68	63.64	54.54	47.75	42.53	38.31	34.91
35	57.84	280.02	150.18	106.45	83.42	68.91	58.86	51.42	45.71	41.12	37.43

Weight Cars and Lading.....1306 Tons
Weight Locomotive..... 173 "
Total Train.....1479 "

Table No. 4
ACCELERATIONS AND RETARDATIONS

Locomotive loaded with maximum train it can handle on 1 per cent. grade at 5 miles per hour maintained speed.

	Locomotive Drifting and Accelerating							Locomotive Drifting and Retarding						
Velocity, Miles Per Hour	—1.0 Grade	—0.9 Grade	—0.8 Grade	—0.7 Grade	—0.6 Grade	—0.5 Grade	—0.4 Grade	—0.3 Grade	—0.2 Grade	—0.1 Grade	0.0 Grade	+0.1 Grade	+0.2 Grade	+0.2 Grade
0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1	.09	.12	.18	.36	.....	.....	.....	2009.00	353.42	193.55	133.56	101.71	82.11	69.26
2	.28	.35	.48	.78	.71	2.16	.....	2007.36	353.13	193.39	133.45	101.63	82.04	69.20
3	.56	.68	.89	1.32	1.49	3.58	7.45	2002.44	352.26	192.92	133.12	101.38	81.84	69.03
4	.92	1.10	1.40	1.97	2.38	4.99	10.78	1994.24	350.82	192.13	132.57	100.96	81.50	68.75
5	1.38	1.64	2.06	2.80	3.51	6.75	14.79	1982.76	348.80	191.02	131.81	100.38	81.03	68.35
6	1.95	2.31	2.86	3.82	4.89	8.91	19.69	1968.00	346.20	189.60	130.83	99.63	80.43	67.84
7	2.62	3.10	3.81	5.02	6.52	11.46	25.48	1949.96	343.04	187.86	129.63	98.72	79.69	67.22
8	3.39	4.01	4.91	6.41	8.49	14.40	32.16	1928.64	339.28	185.81	128.21	97.64	78.82	66.49
9	4.27	5.04	6.15	7.98	10.53	17.73	39.73	1904.04	334.25	183.44	126.57	96.39	77.81	65.64
10	5.25	6.19	5.54	9.74	12.92	21.45	48.19	1876.16	330.05	180.75	124.72	94.98	76.67	64.68
11	6.33	7.46	7.07	11.68	15.56	25.57	57.54	1845.00	324.57	177.75	122.65	93.40	75.40	63.61
12	7.52	8.85	8.75	13.81	18.45	30.08	67.78	1810.56	318.51	174.43	120.36	91.64	73.99	62.42
13	8.81	10.36	10.58	16.12	21.59	34.98	78.91	1772.84	311.87	170.80	117.85	89.75	72.45	61.12
14	10.20	11.99	12.55	18.62	24.98	40.27	90.93	1731.84	304.66	166.85	115.12	87.67	70.77	59.71
15	11.69	13.74	14.67	21.30	28.62	45.95	103.84	1687.56	296.87	162.58	112.18	85.43	68.96	58.18
16	13.29	15.62	16.93	24.17	32.51	52.03	117 64	1640.00	288.50	158.00	109.02	83.02	67.02	56.54
17	14.99	17.62	19.34	27.22	36.65	58.50	132.33	1589.16	279.56	153.10	105.64	80.45	64.94	54.79
18	16.79	19.74	21.90	30.46	41.04	65.36	147.91	1535.04	270.04	147.89	102.04	77.71	62.73	52.93
19	18.70	21.98	24.60	33.88	45.65	72.61	164.38	1477.64	259.94	142.36	98.22	74.80	60.38	50.95
20	20.71	24.34	27.45	37.49	50.58	80.25	181.74	1416.96	249.27	136.51	94.19	71.73	57.90	48.86
21	22.82	26.82	30.44	41.28	55.73	88.29	199.99	1353 00	238.02	130.35	89.94	68.49	55.29	46.66
22	25.04	29.42	33.58	45.26	61.13	96.72	219.13	1285.76	226.19	123.87	85.47	65.09	52.54	44.34
23	27.36	32.14	36.87	49.42	66.78	105.54	239.16	1215.24	213.78	117.08	80.78	61.52	49.66	41.91
24	29.78	34.98	40.30	53.77	72.68	114.75	260.08	1141.44	200.80	109.97	75.87	57.78	46.64	39.37
25	32.30	37.94	43.88	58.30	78.83	124.35	281.89	1064.36	187.24	102.54	70.75	53.88	43.49	36.71
26	34.93	41.03	47.60	63.02	85.23	134.35	304.59	984.00	173.10	94.80	65 41	49.81	40.21	33.92
27	37.66	44.24	51.47	67.92	91.88	144.74	328.18	910.36	158.39	86.74	59.85	45.58	36.79	31.04
28	40.49	47.57	55.49	73.01	98.78	155.52	352.66	813.44	143.10	78.37	54.07	41.18	33.24	28.05
29	43.43	51.02	59.65	78.28	105.93	166.69	378.03	723.24	127.23	69.68	48.07	36.61	29.55	24.94
30	46.47	54.59	63.96	83.74	113.34	178.25	404.29	629.76	110.79	60.67	41.86	31.88	25.73	21.72
31	49.61	58.28	68.41	89.38	121.00	190.21	431.44	533.00	93.77	51.35	35.43	26.98	21.78	18.39
32	52.86	62.09	73.01	95.21	128.91	202.56	459.48	432.96	76.17	41.71	28.78	21.92	17.69	14.94
33	56.21	66.02	77.76	101.22	137.07	215.30	488.41	329.64	57.99	31.76	21.91	16.69	13.47	11.38
34	59.66	70.07	82.65	107.42	145.48	228.43	518.23	223.04	39.24	21.49	14.82	11.29	9.11	7.71
35	63.21	74.24	87.69	113.80	154.14	241.95	548.94	113.16	19.91	10.90	7.52	5.73	4.62	3.92

Locomotive C. T. P. at 5 miles per Hour, 39,000.
Weight of Locomotive, 175 Tons.

Table No. 5
GRADIENTS ON WHICH GIVEN VELOCITY CAN BE MAINTAINED FOR GIVEN TRAIN TONS

Train Resistance, 5.4 Lbs. Per Ton for Velocities 4 Miles to 35 Miles per Hour.

Velocity Miles per Hour	700 Tons	800 Tons	900 Tons	1000 Tons	1100 Tons	1200 Tons	1306 Tons	1400 Tons	1500 Tons	1600 Tons	1700 Tons	1900 Tons	2100 Tons	2400 Tons	2700 Tons	3000 Tons	Velocity Miles perHour
5	1.88	1.66	1.48	1.33	1.21	1.10	1.00	.92	.85	.78	.73	.64	.56	.46	.38	.32	5
6	1.69	1.49	1.33	1.19	1.08	.98	.89	.82	.75	.70	.64	.56	.48	.40	.33	.27	6
7	1.53	1.35	1.20	1.07	.97	.88	.79	.73	.67	.62	.57	.49	.42	.34	.28	.23	7
8	1.40	1.23	1.09	.97	.88	.79	.72	.66	.60	.55	.51	.43	.37	.30	.24	.19	8
9	1.29	1.13	1.00	.89	.80	.72	.65	.60	.55	.50	.46	.39	.33	.26	.20	.16	9
10	1.20	1.05	.93	.82	.74	.66	.60	.55	.50	.45	.41	.35	.29	.23	.175	.13	10
11	1.11	.97	.86	.76	.68	.61	.55	.50	.45	.41	.375	.31	.26	.20	.15	.11	11
12	1.03	.90	.79	.70	.63	.56	.50	.45	.41	.37	.34	.28	.23	.175	.125	.09	12
13	.96	.83	.73	.64	.58	.51	.46	.41	.37	.335	.305	.25	.20	.15	.10	.07	13
14	.89	.77	.67	.59	.53	.47	.42	.37	.33	.30	.27	.22	.175	.125	.08	.05	14
15	.82	.71	.62	.54	.48	.425	.38	.33	.30	.27	.24	.19	.15	.10	.06	.03	15
16	.76	.65	.57	.49	.44	.38	.34	.30	.27	.24	.21	.165	.125	.08	.04	.01	16
17	.70	.60	.52	.45	.40	.345	.30	.27	.24	.21	.18	.14	.10	.06	.02	.005	17
18	.64	.55	.47	.41	.36	.31	.27	.24	.21	.18	.155	.115	.08	.04	.005	.02	18
19	.59	.50	.43	.37	.32	.275	.24	.21	.18	.15	.13	.09	.06	.02	.01	.035	19
20	.54	.45	.39	.33	.28	.24	.21	.18	.15	.12	.105	.07	.04	.005	.025	.05	20
21	.49	.41	.35	.29	.25	.21	.18	.15	.12	.10	.085	.05	.02	.01	.04	.06	21
22	.45	.375	.31	.26	.22	.185	.15	.12	.10	.08	.065	.03	.005	.025	.05	.07	22
23	.41	.34	.28	.23	.19	.16	.13	.10	.08	.06	.045	.015	.01	.04	.06	.08	23
24	.37	.305	.25	.20	.16	.135	.11	.08	.06	.04	.025	.00	.025	.05	.07	.09	24
25	.33	.27	.22	.18	.14	.11	.09	.065	.045	.025	.01	.015	.04	.06	.08	.10	25
26	.30	.245	.19	.16	.12	.09	.07	.05	.03	.01	.005	.03	.05	.07	.09	.11	26
27	.27	.22	.17	.13	.10	.075	.05	.035	.015	.00	.02	.04	.06	.08	.10	.12	27
28	.24	.20	.15	.11	.085	.06	.035	.02	.00	.015	.03	.05	.07	.09	.11	.13	28
29	.22	.18	.13	.095	.07	.045	.02	.005	.015	.025	.04	.06	.08	.10	.12	.135	29
30	.20	.16	.11	.08	.055	.03	.005	.01	.025	.035	.05	.07	.09	.11	.13	.14	30
31	.18	.14	.095	.065	.04	.015	.005	.02	.035	.045	.06	.08	.10	.12	.135	.145	31
32	.16	.12	.08	.05	.025	.00	.015	.03	.045	.055	.07	.09	.11	.125	.140	.15	32
33	.14	.10	.065	.035	.01	.01	.025	.04	.055	.065	.08	.10	.115	.13	.145	.155	33
34	.12	.085	.05	.02	.00	.02	.035	.05	.065	.075	.085	.105	.12	.135	.15	.16	34
35	.11	.07	.04	.01	.01	.03	.045	.06	.075	.085	.09	.11	.125	.14	.155	.165	35

Ascending grades shown above heavy line. Descending grades shown below heavy line.

TRACK SCALES.

By H. T. Porter,
Chief Engineer, Bessemer & Lake Erie Railroad.

In looking over competitive bids for track scales from time to time, the writer never was able to find that there was sufficient information in the plans and proposals of the scale companies by which one could make a comparison of the relative merit and capacity of the scales. In sending a man around to see the scales put in for other parties, the man who visited the scales would get some idea of the service they would give, but the information he would obtain would not be of value to anybody but himself.

In order to get up a set of specifications for our road, from which proposals could be submitted, one of our Assistant Engineers has been making inquiries among scale manufacturers, and persons who at the present time are engaged in other kinds of employment, but who in the past have designed scales, and the writer submits herewith a proposed set of specifications for 46-ft., 150-ton, four-section track scale, and for a 60-ft., 150-ton, six-section track scale.

We do not submit these specifications as a finished product, but as a first effort. This is a subject on which there is very little information readily available, and the writer thinks that a move should be made to standardize track scales. We once asked for bids on track scales without any attempt to give particular specifications, and were advised by one of the scale companies that by reason of the variations in details and methods of figuring, they could furnish 49 different kinds of scales under those requirements, and asked to have a man sent on to look over their plans and determine which would best suit us. This is merely mentioned to show the necessity of standardizing, as a great many of the variations in the construction have no special merit, but became necessary to satisfy the whims of the draftsman in the office of the purchaser.

GENERAL SPECIFICATIONS FOR 150-TON 46-FT. TRACK SCALE.

BESSEMER & LAKE ERIE RAILROAD COMPANY.

Plans.

Each bidder shall submit a strain and stress diagram of the scale he intends to furnish, showing thereon the proposed sections of the various parts under strain, and all plans showing details similar to those intended to be used in the construction of this special scale; these plans to be submitted at the time of making his bid.

Length.

The length of this scale shall be known as 46 ft.; this length to be the distance between the ends of the live rail. The ends of the live rail

should be vertically above a point located not less than one-fifth of the distance between the first and second section, distant from the center of the end section of the scale.

Number of Sections.

There shall be four (4) sections.

Rating.

The rating of this scale shall be known as 150-ton 46-ft. track scale, and this load shall be used in the design, each section to be considered as taking one-fourth of the rated tonnage, or 37.5 tons live load.

Dead Load.

The dead load of any part may be neglected when the strain produced by it is less than 2½ per cent. of the strain produced by the rated load.

Impact.

An impact equal to 100 per cent. of the rated load shall be everywhere added, in designing.

Grade.

The maximum grade to which the scale rails will ever be laid is 0.3 per cent., and such grade shall be obtainable by tapered shims to be placed between the bottom of platform stringers and supports, these shims to be omitted should the purchaser desire to have the scale rails level.

Load Adjustment.

Means should be provided by wedge blocks or other device for taking up any minor irregularities of the platform supports, on account of variations in manufacture or setting.

Deck.

The scale deck will be of the rigid type, supported by the pit walls, and will overhang the ends of the platform stringers to correspond with the design of the platform length, relatively to the lengths between sections.

Stringers.

The stringers shall be I-beams of Carnegie structural steel, Manufacturer's Specifications for Steel for Railway Bridges.

The span shall be considered as the c. to c. distance between any two sections, and the maximum bending stress calculated shall not exceed 16,000 lbs. per sq. in., assuming no continuous action over supports.

The minimum depth of I-beams shall be 24 in.

The stringers shall be thoroughly braced laterally by angles not less than 3 in. in width, and by transverse diaphragms. Connections to have ¾-in. rivets or larger. No structural parts shall be less than ⅜-in. thick.

Special Clause.
Structural Steel.

The manufacturer will submit general plan of structural steel showing sizes and total estimated weight, at the time of making his bid, and all necessary scale dimensions in final plan, after contract is signed, which will enable a structural manufacturer to fabricate the steel to fit the scale details.

Suspension Bearings.

The load of the platform shall be transmitted to the main levers by means of suspension bearings. No forged links shall vary more than 1/16-in. from the dimensions shown on the plans.

Levers.

Main levers shall be of cast steel. Other levers may be of cast iron or of cast steel. Level tabs shall be cast on tops of levers about 12 in. c. to c. and faced accurately.

The unit stresses in levers shall not exceed the following values:

Cast-iron, 3,000 lbs. maximum tensile stress.

Cast-iron, 18,000 lbs. maximum compressive stress.

Cast-steel, 8,000 lbs. maximum tensile stress.

Knife Edges.

The knife edges shall be separate from the bearing in main and extension levers and of silico-manganese steel; the load per linear inch of knife edge shall not exceed 5,000 lbs. Th lin of knife edges in any one lever should coincide as nearly as practicable with the neutral axis of the lever.

Bearing Blocks.

Cast-steel bearing blocks, self-centering the bearing on supports, shall support the knife edges.

Supports.

The scale levers shall be supported by cast-steel standards resting on concrete pedestals, and no parts subject to tensile strain shall have a unit stress exceeding 8,000 lbs.

The bearing on the concrete shall not exceed 300 lbs. per sq. in.

Check Rods.

Check rods shall be provided transversely and longitudinally.

Multiple.

The multiple of the beam pull shall be 800, but an additional rod whose pull is 400 shall be provided for attaching to 2 to 1 lever of Streeter-Amet Recorder.

Beam.

The main beam shall be graduated in thousands of pounds, up to 200,000 lbs. An auxiliary sliding poise attached to the main latched roller poise shall move over graduations of 50 lbs. for 1,000 lbs. All weights in excess of 200,000 lbs. to be hung from the end of the beam.

The graduated scales shall be of brass.

Painting.

All parts, except wearing points and brass, shall be painted before shipment.

Foundation Plan.

The scale manufacturer shall furnish a foundation plan showing all necessary dimensions to install the scale. The pit shall be amply wide to permit thorough inspection and make all parts accessible.

Purchaser Furnishes.

The purchaser will construct the foundation to the dimensions shown by the manufacturer's plan and will place all bolts and structural steel that is to be built into the masonry. The purchaser will also furnish and construct the deck, weather guards around rail chairs, scale house, and provide foundation bolts, 100 lbs. scale rails and fastenings. Purchaser will furnish structural steel to fit dimensions shown on scale plans.

Easer Rails.

Easer rails will be provided for both ends of the scale by the purchaser, but the scale manufacturer shall not consider the length of the platform as affected thereby.

Superintendence.

The manufacturer will be notified when foundation is completed, and he shall furnish a competent erecting foreman to superintend the installation of the scales; any assistance this foreman may need will be supplied by the purchaser. Erecting foreman will be paid for at a rate per day as specified in the bid.

Inspection of Material, etc.

All material or workmanship shall be subject to the inspection of the purchaser's representatives.

Guarantee.

All parts failing as a result of defective material or workmanship of any parts furnished by the manufacturer shall be replaced free of extra cost to the purchaser.

GENERAL SPECIFICATIONS FOR 150-TON, 60-FT. TRACK SCALE.

BESSEMER & LAKE ERIE RAILROAD COMPANY.

Plans.

Each bidder shall submit a strain and stress diagram of the scale he intends to furnish, showing thereon the proposed sections of the various parts under strain, and all plans showing details similar to those intended to be used in the construction of this special scale; these plans to be submitted at the time of making his bid.

Length.

The length of this scale shall be known as 60 ft.; this length to be the distance between the ends of the live rail. The ends of the live rail should be vertically above a point located not less than one-third of the distance between the first and second section, distant from the center of the end section of the scale.

Number of Sections.

There shall be six (6) sections.

Rating.

The rating of this scale shall be known as 150 tons, 60-ft. Track Scale for Continuous Service, and this load shall be used in the design, each section to be considered as taking one-fourth of the rated tonnage, or 37.5 tons live load.

Dead Load.

The dead load of any part may be neglected where the strain produced by it is less than 2½ per cent. of the strain produced by the rated load.

Impact.

An impact equal to 100 per cent. of the rated load shall be everywhere added, in designing.

Grade.

The grade to which the scale rails will usually be laid is 0.5 per cent., although this may be varied either way to suit local conditions. The grade shall be obtainable by insertion of tapered shims between the bottom of platform stringers and supports, these shims to be omitted should the purchaser desire to have the scale rails level.

Load Adjustments.

Means should be provided by wedge blocks or other device for taking up any minor irregularities of the platform supports, on account of variations in manufacture or setting.

Deck.

The scale deck will be of the rigid type, supported by the pit walls, and will overhang the ends of the platform stringers to correspond with the design of the platform length, relatively to the lengths between sections.

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The span shall be considered as the c. to c. distance between any two sections, and the maximum bending stress calculated shall not exceed 16,000 lbs. per square in., assuming no continuous action over supports.

The minimum depth of I-beams shall be 24 in.

The stringers shall be thoroughly braced laterally by angles not less than 3 in. in width, and by transverse diaphragms. Connections to have ¾-in. rivets or larger. No structural parts shall be less than ⅜ in. thick.

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Cast-steel, 8,000 lbs. maximum tensile stress.

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Bearing Blocks.

Cast-steel bearing blocks, self-centering the bearing on supports, shall support the knife edges.

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Easer rails will be provided for both ends of the scale by the purchaser, but the scale manufacturer shall not consider the length of the platform as affected thereby.

Superintendence.

The manufacturer will be notified when foundation is completed, and he shall furnish a competent erecting foreman to superintend the installation of the scales; any assistance this foreman may need will be supplied by the purchaser. Erecting foreman will be paid for at a rate per day as specified in the bid.

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All material or workmanship shall be subject to the inspection of the purchaser's representatives.

Guarantee.

All parts failing as a result of defective material or workmanship of any parts furnished by the manufacturer shall be replaced free of extra cost to the puchaser.

HISTORY OF AN OLD IRON BRIDGE.

By George K. Lowell,
General Manager, Detroit, Toledo & Ironton Railway.

Below is a brief history of the Iron Railroad, together with the original constuction of the Iron Bridge, spanning Storms Creek, on the line of the Iron Railroad, two and one-half miles north of Ironton, O.

Construction of the Iron Railroad was originally commenced in the year 1849, and the line was completed to the Vesuvius Mines, about six miles north of Ironton, during the year 1850. The track was laid with strap rail laid on wooden stringers, and the stringers laid on cross-ties spaced six feet apart. John Campbell, John Peters and others, of the Ohio Coal & Iron Company, were the original founders of the Iron Railroad.

In the construction of the Iron Railroad it became necessary to span Storms Creek, two and one-half miles north of Ironton. In the original construction of the Iron Railroad, Storms Creek was spanned with a wooden trestle bridge, 97 ft. in length, but during the year 1857 the structure was considered insufficient to carry the increased loading of the road's equipment, and it was decided to construct an iron bridge of larger capacity, and more safe for the operation of the railroad. Thomas W. H. Moseley, a Civil and Constructing Engineer, of Kentucky, was called upon to prepare a plan for the construction of a wrought-iron bridge to be placed on the site of the wooden structure spanning Storms Creek. The plans were prepared for what is known as Bowstring Construction Iron Bridge, patented February 8, 1857, and constructed by Moseley & Company, of Cincinnati, O., in the year 1859, the bridge being constructed for the loading of 2,000 lbs per linear foot, live load.

In the year 1905, the Detroit, Toledo & Ironton Railway, successors to the Iron Railroad, increased the weight of its locomotives and cars, and it was necessary to strengthen this bridge by placing timber trestle bents under the floor or track system. With this addition, the bridge, as originally constructed, is still in use, and over it passes as heavy tonnage as on any road in this section of the country.

Figs. 1 and 2 are photographs of the bridge in its present condition. Fig. 3 is a photograph of one of the 200-ton engines operated daily over the structure.

FIG. 1.

FIG. 2.

Fig. 3.

FOREWORD.

In line with the policy pursued heretofore, to collect and disseminate useful information pertaining to the objects of the Association, the Board of Direction, through the courtesy of Mr. C. A. Morse, Chief Engineer, and Mr. A. F. Robinson, Bridge Engineer, of the Atchison, Topeka & Santa Fe Railway System, is enabled to present herewith a valuable report on "Tests of Long-leaf Pine Bridge Timbers," prepared by Mr. H. B. MacFarland, Engineer of Tests of that Railway System.

Vacuum started, 2:45 p. m.
Maximum vacuum, inches, 26.
Vacuum broken, 4:15 p. m.
Run closed, 4:30 p. m.
Time consumed in run, 4 hours and 40 minutes.
Process, Full-Cell Creosote.

Each specimen was weighed after treatment, in order to calculate the amount of creosote absorbed per cubic foot.

The 64 pieces were loaded and shipped to the testing laboratory at Topeka immediately after treatment. It was desirable to study the effect of the creosoting on the timbers both immediately after treatment and one year after treatment. Therefore, the 34 untreated specimens and 16 of the treated specimens were tested immediately upon receipt at Topeka and the remaining 16 treated specimens were tested after one year, having been seasoned during the year by laying in an open pile in the yard at Topeka.

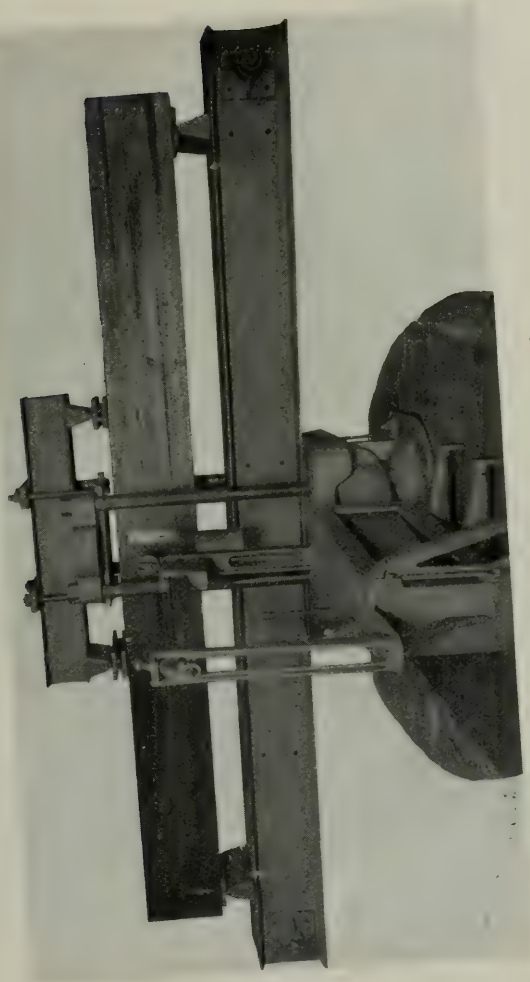
Two special specimens were prepared with the others, in order to compare the relative strength of the butt and top portions of the tree. Specimen 13 was the top end and 14 the butt end of one large stick. Both of these were left untreated. Specimen 40 was the top end and 39 the butt end of another large stick. Both of these were treated. All four were tested. It was impossible to determine which was the butt end of the regular specimens, but the two special sticks showed this by position of the sapwood and growth rings.

METHODS.

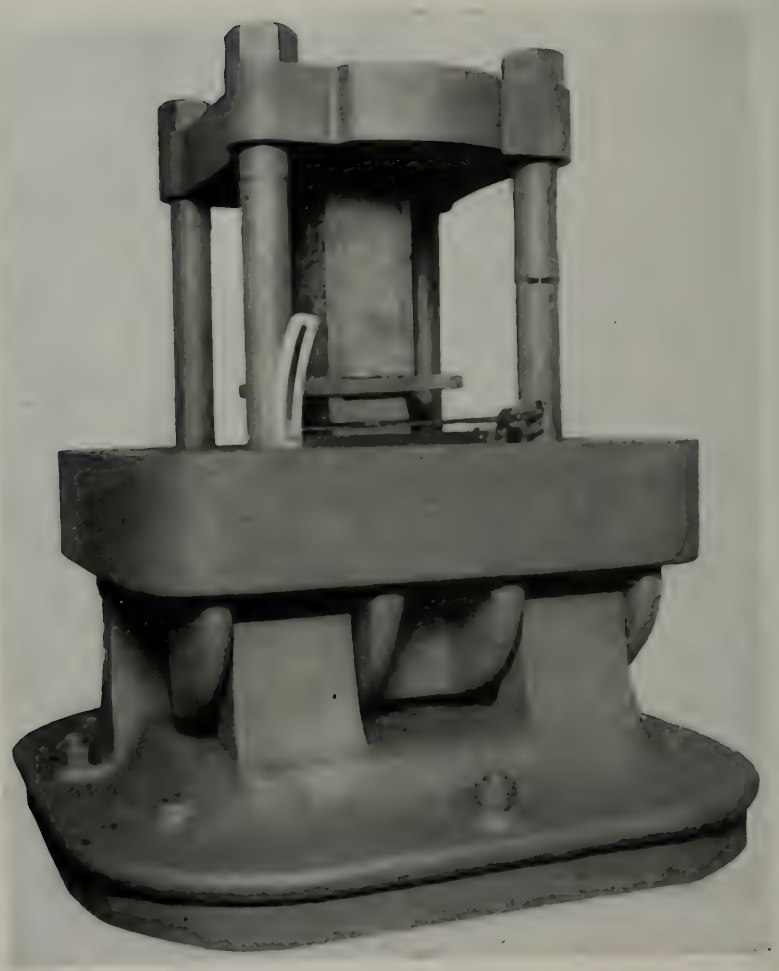
The photograph on page 33 shows the method of making the transverse test. The stringer was supported on rocking knife edges placed 13 ft. apart on the bed of an Olsen 200,000 lb. testing machine. Six-inch flat plates were placed between the knife edges and the timber to prevent cutting. The load was applied at third points through knife edges and six-inch plates and rollers. An initial load of 500 lbs. was used in order to get a firm bearing on the plates. The deflections were measured by a mirror and adjustable scale and a fine wire, which was fastened at the center of the beam directly above each knife edge. The load was applied with the machine running at a speed of 0.16 inch per minute.

The photograph on page 34 shows a specimen under test in compression parallel to the grain. The piece is 5 in. x 5 in. x 12 in. A ball and socket plate was placed between the machine bed and the specimen in order that the load might be uniformly applied. Deflections were read by means of a deflectometer. The load was applied at a rate of 0.16 inch per minute.

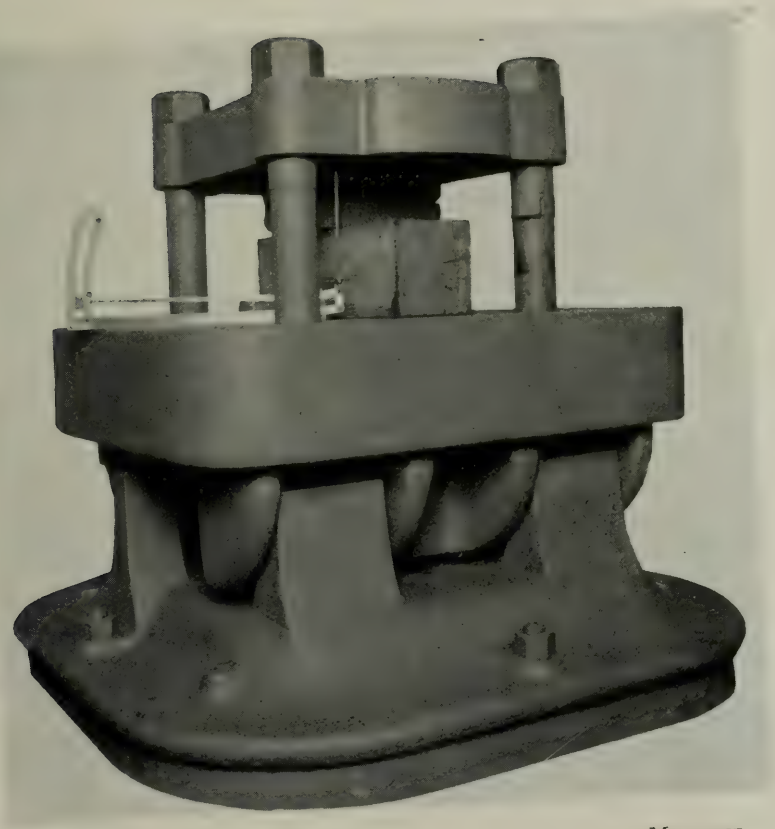
The photograph on page 35 illustrates the method of making test in compression perpendicular to the grain. The specimens were 6 in. x 6 in. x 24 in., and the load was applied through a four-inch plate with slightly rounded corners. The machine speed used was 0.16-inch per minute. A deflectometer was used to measure deflections.



TRANSVERSE TEST—SPECIMEN IN MACHINE.



COMPRESSION PARALLEL TO GRAIN—TEST SPECIMEN IN MACHINE.



COMPRESSION PERPENDICULAR TO GRAIN—TEST SPECIMEN IN MACHINE.

The moisture determinations were, in all cases, made immediately after transverse tests. The samples were obtained by boring nine one-inch holes, one-half inch deep, spaced uniformly, in the end of the specimen. The chips were carefully weighed on a balance and then placed in an oven and kept at a temperature of 200 degrees Fahrenheit for eight hours. The per cent. of moisture was calculated from the loss in weight. The percentage is that of dry weight of specimen.

The data regarding number of growth rings per inch were obtained from the large specimens. The rings were counted, starting one inch from the heart and counting for a radius of three inches. The per cent. of sapwood was estimated from measurements of the end area.

FORMULAE.

The following formulæ were used in the calculations:

TRANSVERSE TEST.—Load applied at third points.

Load in lbs. per sq. in.:

$$S = \frac{PL}{bd^2} \text{ where,}$$

P = Load in lbs.
L = Length of span in inches
b = Breadth of specimen in inches
d = Depth of specimen in inches
S = Stress in lbs. per sq. in.

Modulus of Rupture:

$$R = \frac{PL}{bd^2} \text{ where,}$$

P = Maximum load in lbs.
R = Modulus of rupture in lbs. per sq. in.
Other symbols as above.

Modulus of Elasticity:

$$E = \frac{PL^3}{4.7bd^3D} \text{ where,}$$

E = Modulus of elasticity in lbs. per sq. in.
P = Load at elastic limit in lbs.
D = Deflection in inches at elastic limit.
Other symbols as above.

Horizontal Shear at Neutral Axis:

$$V = \frac{3P}{4bd} \text{ where,}$$

V = Horizontal shear at neutral axis, lbs. per sq. in.
P = Maximum load in pounds.
Other symbols as above.

COMPRESSION PARALLEL TO GRAIN:

Load in lbs. per sq. in.:

$$S = \frac{P}{A} \text{ where,}$$

P = Applied load in lbs.
A = Area of section of test piece in sq. in.
S = Load in lbs. per sq. in.

Modulus of Elasticity:

$$E = \frac{PL}{AD} \text{ where,}$$

P = Load at elastic limit in lbs.
D = Deflection in inches at elastic limit.
E = Modulus of elasticity, lbs. per sq. in.
Other symbols as above.

COMPRESSION PERPENDICULAR TO GRAIN:

Load in lbs. per sq. in.:

$$S = \frac{P}{A} \text{ where,}$$

A = Area of compression plate in sq. in.
Other symbols as above.

The elastic limits were taken from the curves.

DATA.

The results in detail are shown on the following pages. The data obtained have been plotted as shown on the diagrams. Below the curves are diagrams showing the lines of failure for the pieces in transverse test, also in compression parallel and perpendicular to the grain. The end views give general locations of growth rings of each specific test.

The individual data sheets for the different specimens are arranged in numerical order and not according to the year in which tested. The summary sheets group, for the purpose of ready comparison, the results of untreated specimens tested in January, 1911, with the treated specimens of the same timber tested in January, 1912. Specimens 13, 14, 39 and 40 were special tests made in January, 1911, and results obtained are not shown in the general summaries of specimens tested in January, 1911. The specimens were tested as follows:

January, 1911.						January, 1912.	
1	13	23	33	45	56	2	34
3	14	25	35	47	57	6	38
4	15	26	36	49	58	8	42
5	17	27	37	51	59	10	44
7	18	28	39	52	60	16	46
9	19	29	40	53	61	20	48
11	21	30	41	54	62	24	50
12	22	31	43	55	63	32	64

SPECIMEN NO. 1—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x6.68
Weight, lbs. per cu. ft.	42.2
Moisture, per cent	18.2
Rings, per inch	8
Sap, per cent	12

This piece had many small knots showing on one side, and a large knot along the neutral axis, showing on the opposite side. Failed in horizontal shear, the large knot diverting the fracture.

Elastic limit, lbs. per sq. in.	5,000
Modulus of rupture, lbs. per sq. in.	5,290
Modulus of elasticity, lbs. per sq. in.	1,850,000
Maximum horizontal shear, lbs.	407
Deflection at failure, inches	0.93

Compression Parallel to Grain.

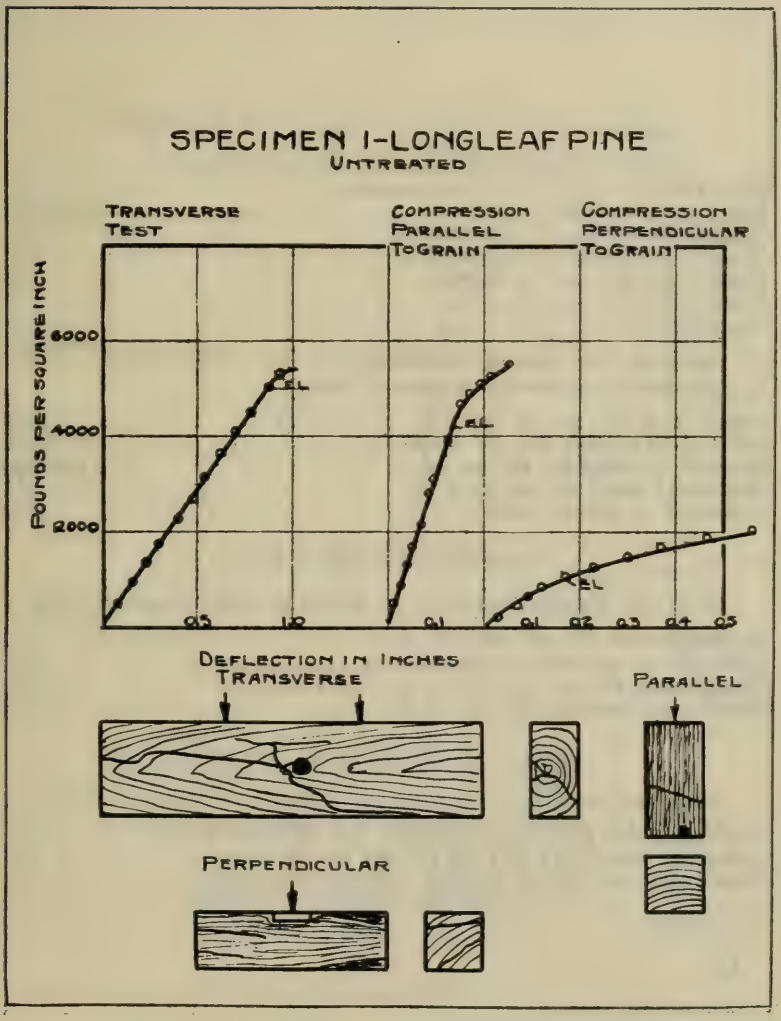
Specimen had a few knots and was straight grained. Failed by shearing across the center.

Maximum load, lbs. per sq. in.	6,510
Deflection at maximum load, in.	0.25
Elastic limit, lbs. per sq. in.	4,200
Modulus of elasticity, lbs. per sq. in.	360,000

Compression Perpendicular to Grain.

Specimen slightly cross-grained, with some sap. Failure was by splitting horizontally at one end.

Deflection under load of 2,031 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,100


SPECIMEN 1-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
0.5
1.0
0.1
0.1
0.2
0.3
0.4
0.5
DEFLECTION IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 2—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.19x7.06
Weight, lbs. per cu. ft., treated	50.4
Weight, lbs. per cu. ft., untreated	43.8
Weight, lbs. per cu. ft., increase	6.6
Rings, per inch	8
Sap, per cent	12

Specimen was straight grained, with a few weather checks. Failed by horizontal shear through center of heart.

Elastic limit, lbs. per sq. in.	4,775
Modulus of rupture, lbs. per sq. in.	6,016
Modulus of elasticity, lbs. per sq. in.	1,840,000
Horizontal shear, lbs. per sq. in.	467
Deflection at failure, inches	0.70

Compression Parallel to Grain.

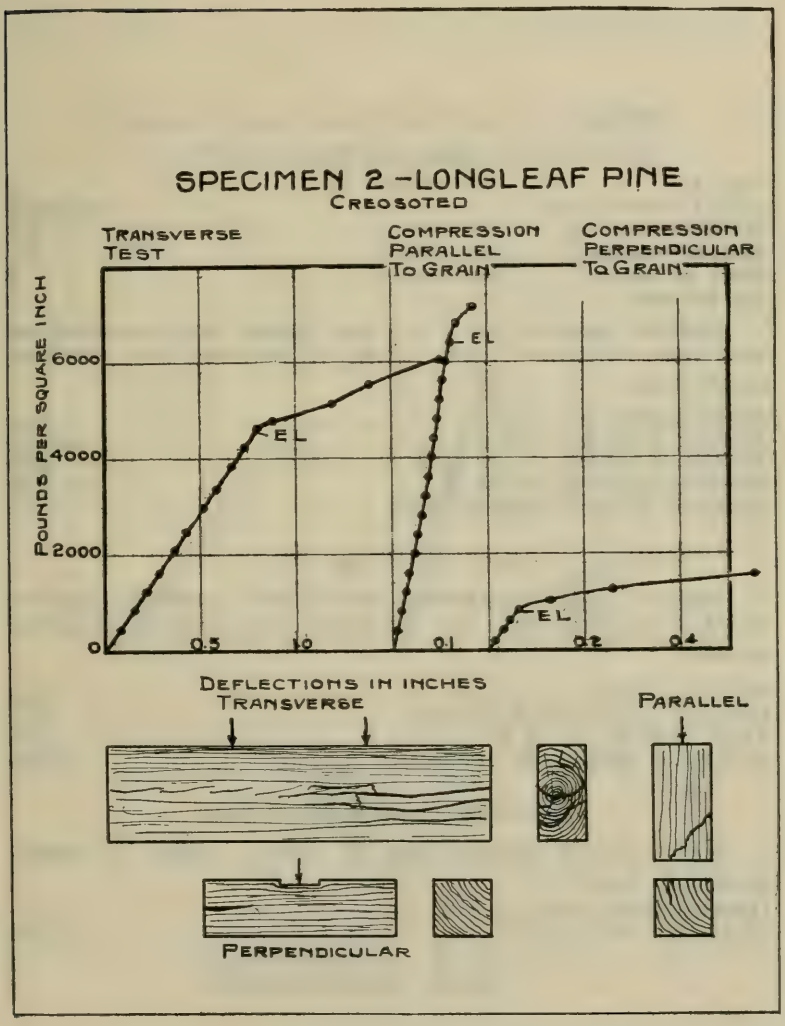
Stick was slightly cross-grained. Failed by splitting and crushing.

Maximum load, lbs. per sq. in.	7,143
Deflection at maximum load, inches	0.17
Elastic limit, lbs. per sq. in.	6,000
Modulus of elasticity, lbs. per sq. in.	630,000

Compression Perpendicular to Grain.

Piece had one small knot near end, but no other defects. Failed by crushing under plate, fibre breaking and splitting to end.

Deflection under load of 1,565 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	800


SPECIMEN 2 -LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
0
0.5
1.0
0.1
0.2
0.4
EL
EL
EL
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 5—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.30x6.97
Weight, lbs. per cu. ft.	45.5
Moisture, per cent	18.5
Rings, per inch	8
Sap, per cent	15

Specimen apparently of a very poor grade, having sapwood and wind shake the entire length. Failed in horizontal shear following annular rings.

Elastic limit, lbs. per sq. in.	4,200
Modulus of elasticity, lbs. per sq. in.	1,480,000
Modulus of rupture, lbs. per sq. in.	4,880
Horizontal shear, lbs. per sq. in.	383
Deflection at time of rupture, inches	1.24

Compression Parallel to Grain.

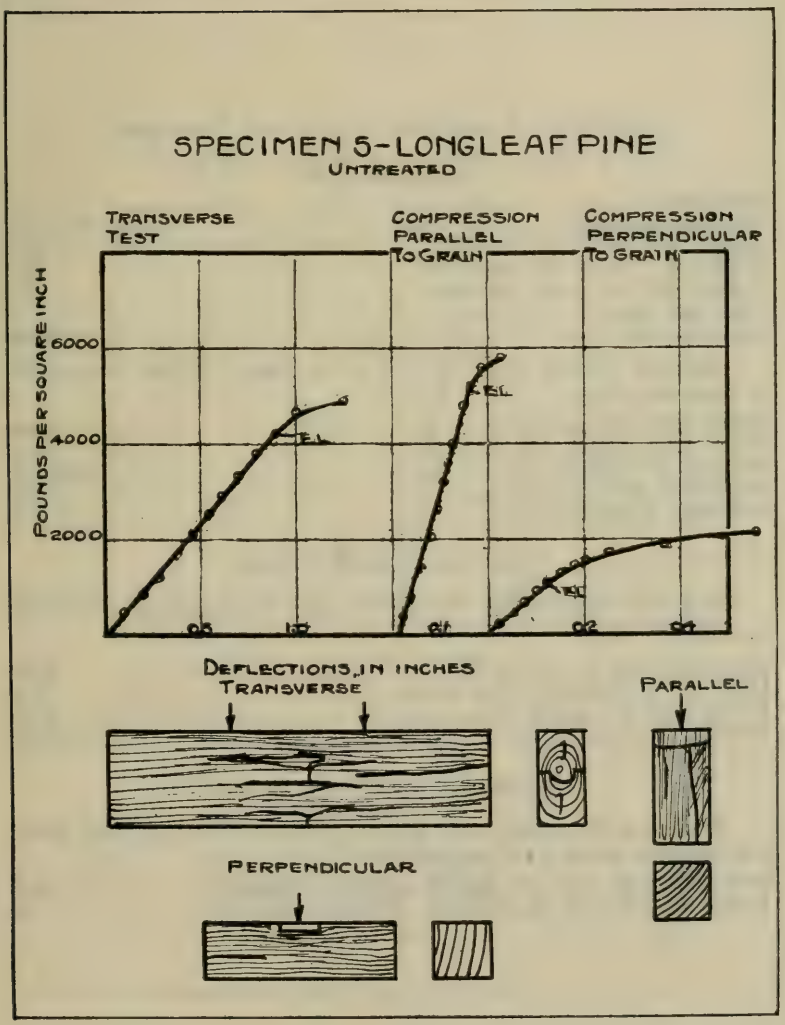
Specimen was straight-grained and showed considerable sapwood. Failed by crushing across top and splitting downward the length of specimen.

Maximum load, lbs. per sq. in.	5,904
Deflection at maximum load, inches	0.232
Elastic limit, lbs. per sq. in.	5,100
Modulus of elasticity, lbs. per sq. in.	386,000

Compression Perpendicular to Grain.

Straight-grained specimen with no defects. Failed by splitting horizontally at one end.

Deflection under load of 2,108 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,100


SPECIMEN 5-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
E.L.
E.L.
E.L.
DEFLECTIONS, IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 6—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.4x7.24
Weight, lbs. per cu. ft., treated	46.3
Weight, lbs. per cu. ft., untreated	38.8
Weight, lbs. per cu. ft., increase	7.5
Rings, per inch	8
Sap, per cent	None

Specimen checked badly and had a few knots. Failure was caused by horizontal shear.

Elastic limit, lbs. per sq. in.	4,400
Modulus of rupture, lbs. per sq. in.	4,517
Modulus of elasticity, lbs. per sq. in.	1,390,000
Horizontal shear, lbs. per sq. in.	356
Deflection at failure, inches	1.12

Compression Parallel to Grain.

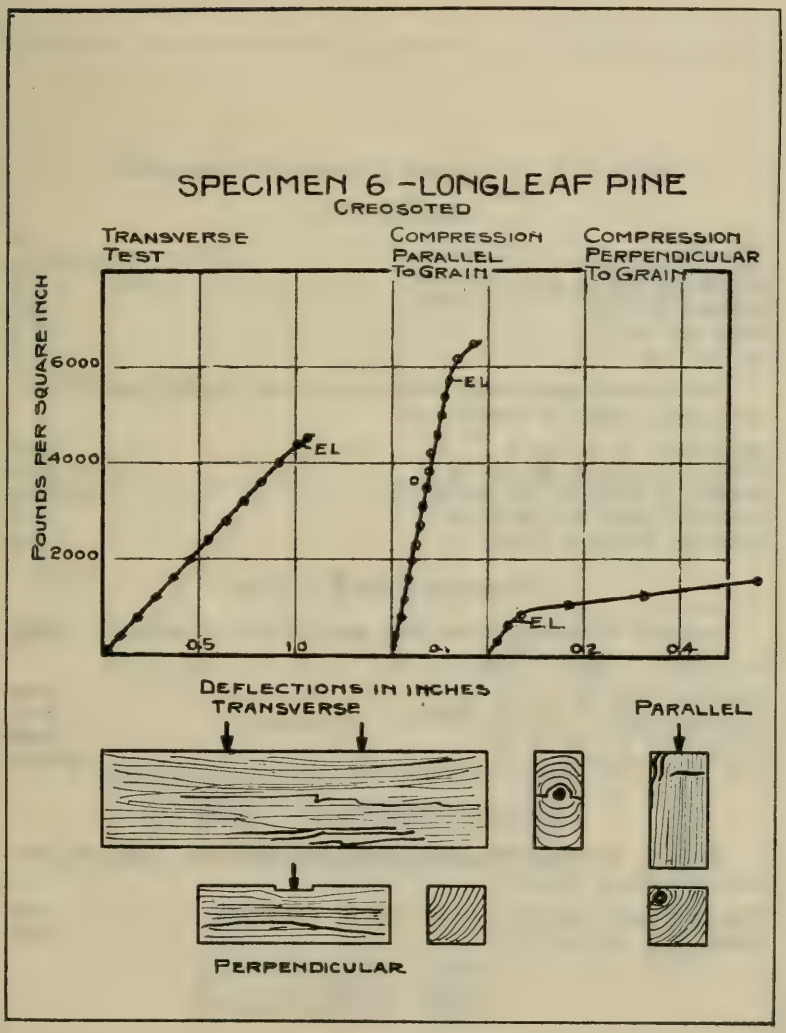
Stick had small checks, but showed clear straight grain. Failed by crushing on top.

Maximum load, lbs. per sq. in.	6,460
Deflection at maximum load, inches	0.17
Elastic limit, lbs. per sq. in.	5,725
Modulus of elasticity, lbs. per sq. in.	575,000

Compression Perpendicular to Grain.

Piece was straight-grained, with no defects. Failed by fiber breaking, crushing under plate and splitting to end.

Deflection under load of 1,542 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	700


SPECIMEN 6 -LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
E.L.
E.L.
E.L.
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 7—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.31
Weight, lbs. per cu. ft	38.5
Moisture, per cent	18.1
Rings, per inch	8
Sap, per cent	11

Piece showed many small knots on one side. Failure was by horizontal shear along the neutral axis.

Elastic limit, lbs. per sq. in	4,000
Modulus of rupture, lbs. per sq. in	4,760
Modulus of elasticity, lbs. per sq. in	1,416,000
Horizontal shear, lbs. per sq. in	372
Maximum deflection, inches	1.4

Compression Parallel to Grain.

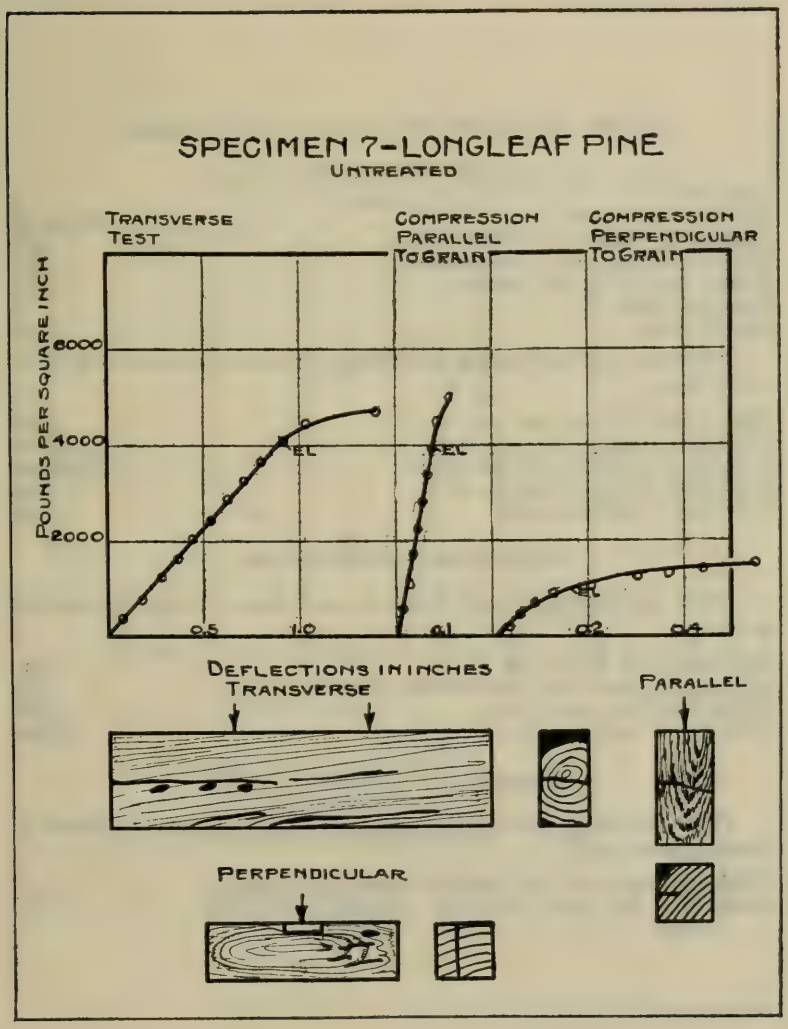
Specimen was cross-grained, with small amount of sapwood. Failed by crushing at center of piece.

Maximum load, lbs. per sq. in	5,070
Deflection at maximum load, inches	0.115
Elastic limit, lbs. per sq. in	4,000
Modulus of elasticity, lbs. per sq. in	585,750

Compression Perpendicular to Grain.

Specimen showed spike knot, checks and sapwood. Failed by splitting vertically at one end.

Deflection under load of 1,564 lbs. per sq. in., inches	0.55
Elastic limit, lbs. per sq. in	1,000


SPECIMEN 7-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 8—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.13x7.38
Weight, lbs. per cu. ft., treated	54.8
Weight, lbs. per cu. ft., untreated	44.5
Weight lbs. per cu. ft., increase	10.3
Rings, per inch	8
Sap, per cent	11

Specimen had heart shake and checks. Failure was caused by horizontal shear.

Elastic limit, lbs. per sq. in	4,600
Modulus of rupture, lbs. per sq. in	6,658
Modulus of elasticity, lbs. per sq. in	1,640,000
Horizontal shear, lbs. per sq. in	505
Deflection at failure, inches	1.68

Compression Parallel to Grain.

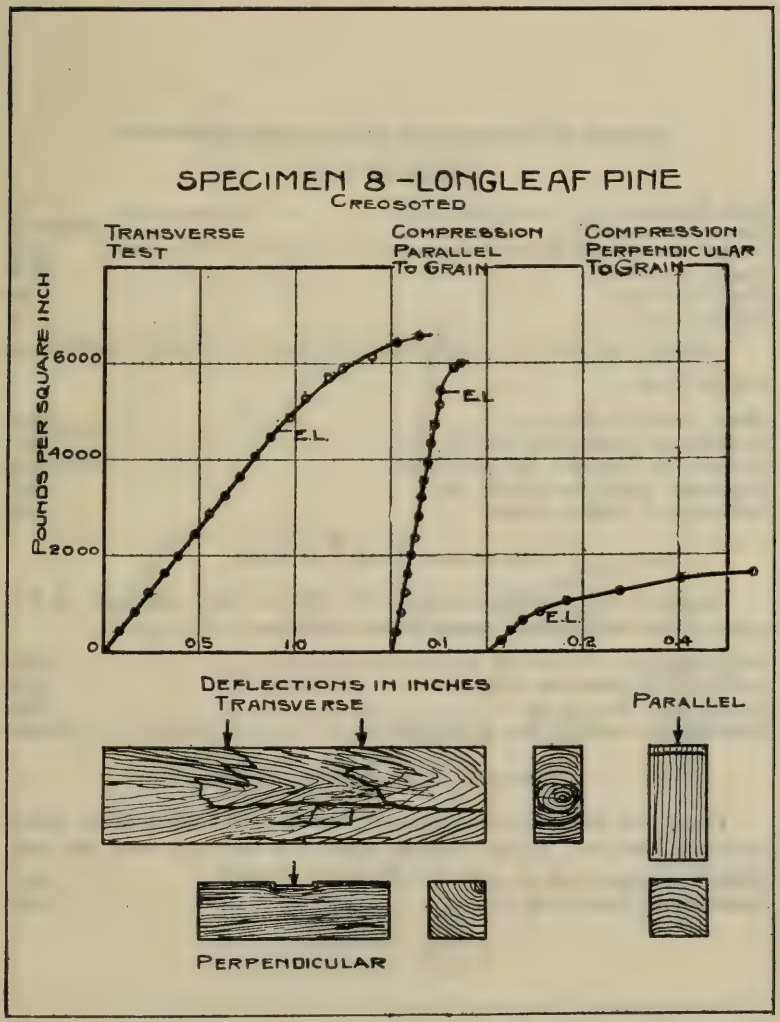
Stick was straight-grained, but had heart shake. Failed by crushing at top.

Maximum load, lbs. per sq. in	5,997
Deflection at maximum load, inches	0.149
Elastic limit, lbs. per sq. in	5,400
Modulus of elasticity, lbs. per sq. in	648,000

Compression Perpendicular to Grain.

Piece had check through heart, but was straight-grained. Failed by crushing under plate.

Deflection under load of 1,668 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	625


SPECIMEN 8 -LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
0
E.L.
E.L.
E.L.
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 9—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	15.95x7.14
Weight, lbs. per cu. ft	42.9
Moisture, per cent	17.8
Rings, per inch	19
Sap, per cent	7

Specimen showed a few small knots. Failed in horizontal shear along annular rings.

Elastic limit, lbs. per sq. in	5,400
Modulus of rupture, lbs. per sq. in	5,480
Modulus of elasticity, lbs. per sq. in	1,591,000
Horizontal shear, lbs. per sq. in	448
Deflection at failure, inches	1.22

Compression Parallel to Grain.

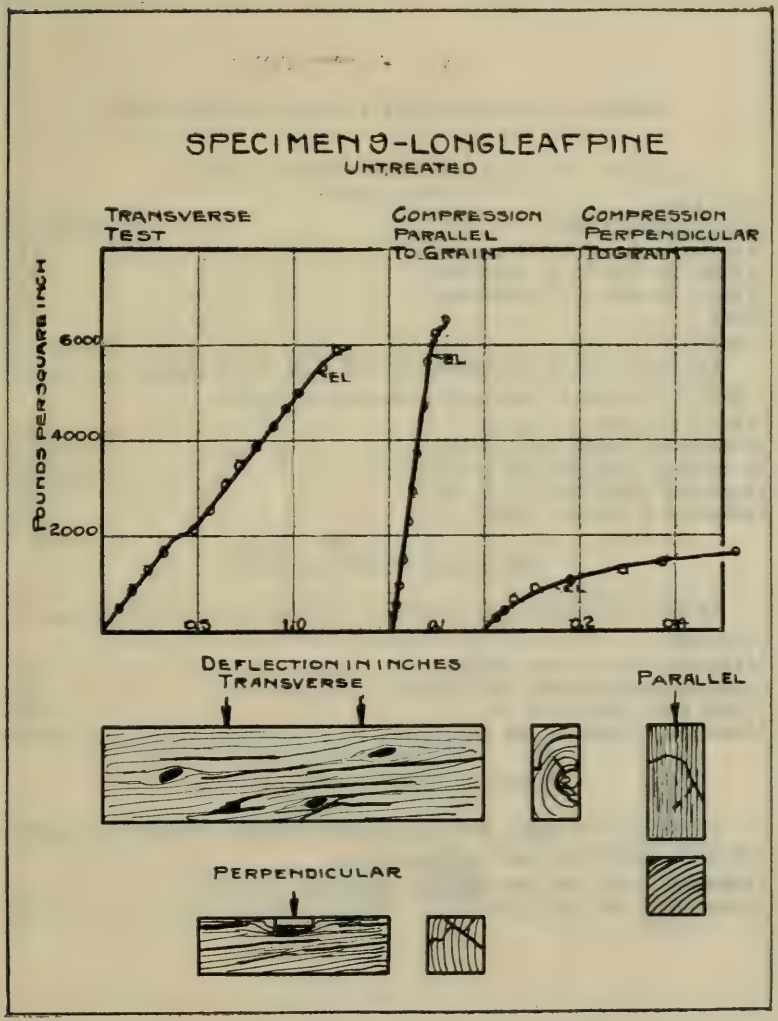
Specimen was straight-grained and showed some sapwood at the ends. Failed by shearing across center of piece.

Maximum load, lbs. per sq. in	6,571
Deflection at maximum load, inches	0.12
Elastic limit, lbs. per sq. in	5,800
Modulus of elasticity, lbs. per sq. in	842,450

Compression Perpendicular to Grain.

Piece was badly cracked, showed sap at ends and a large sound knot near one end. Failure was by splitting horizontally near one end.

Deflection under load of 1,689 lbs. per sq. in., inches	0.53
Elastic limit, lbs. per sq. in	1,000


SPECIMEN 9-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
.05
1.0
.01
.02
.04
DEFLECTION IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 10—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x7.10
Weight, lbs. per cu. ft., treated	54.3
Weight, lbs. per cu. ft., untreated	46.1
Weight, lbs. per cu. ft., increase	8.2
Rings	19
Sap, per cent	7

Specimen was free from knots, but had small shakes and checks. Failed by horizontal shear and cross-grained tension.

Elastic limit, lbs. per sq. in	6,000
Modulus of rupture, lbs. per sq. in	6,006
Modulus of elasticity, lbs. per sq. in	1,807,000
Horizontal shear, lbs. per sq. in	462
Deflection at failure, inches	1.07

Compression Parallel to Grain.

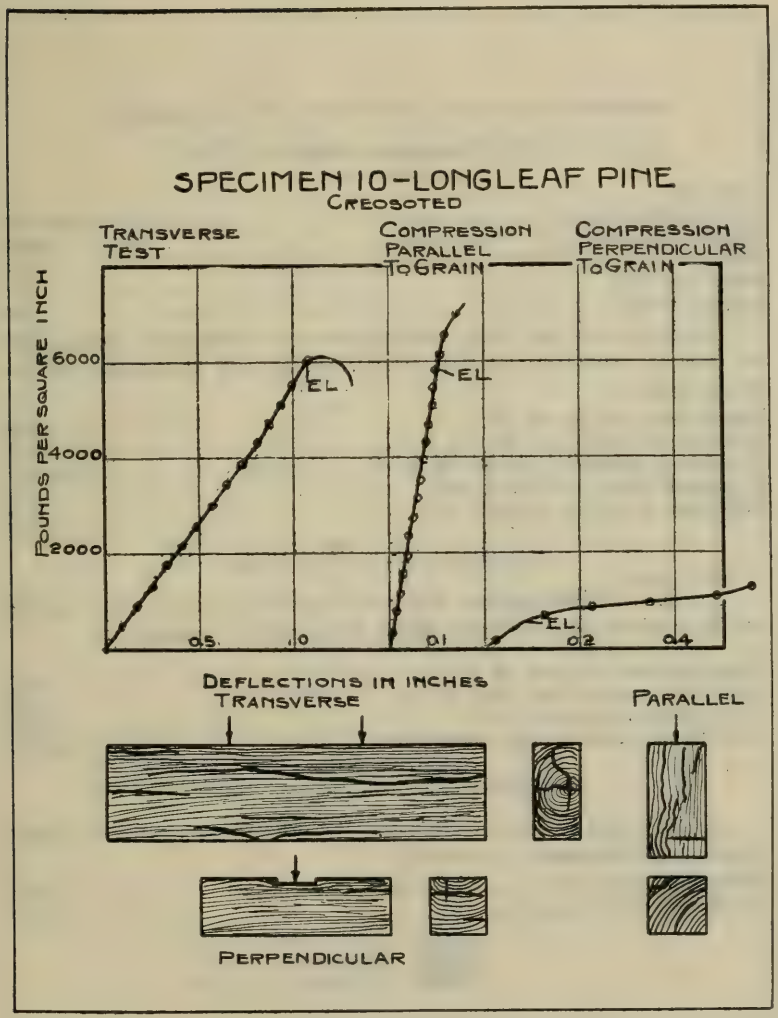
Specimen had curly grain at bottom. Failed at bottom by splitting and crushing.

Maximum load, lbs. per sq. in	6,951
Deflection at maximum load, inches	0.107
Elastic limit, lbs. per sq. in	5,800
Modulus of elasticity, lbs. per sq. in	703,000

Compression Perpendicular to Grain.

Specimen had shake, but was straight-grained. Failed by crushing out from under plate and splitting to end.

Deflection under load, of 1,875 lbs. per sq. in	0.56
Elastic limit, lbs. per sq. in	550


SPECIMEN 10-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
.05
.10
.01
.02
.04
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 11—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.20x7.05
Weight, lbs. per cu. ft	41.5
Moisture, per cent	17.1
Rings, per inch	17
Sap, per cent	20

Specimen was very knotty, and had one very large wind shake. Failure was by splintering tension on the bottom and cross-grain tension on the sides.

Elastic limit, lbs. per sq. in	3,800
Modulus of rupture, lbs. per sq. in	4,980
Modulus of elasticity, lbs. per sq. in	1,429,000
Horizontal shear, lbs. per sq. in	387
Deflection at failure, inches	1.25

Compression Parallel to Grain.

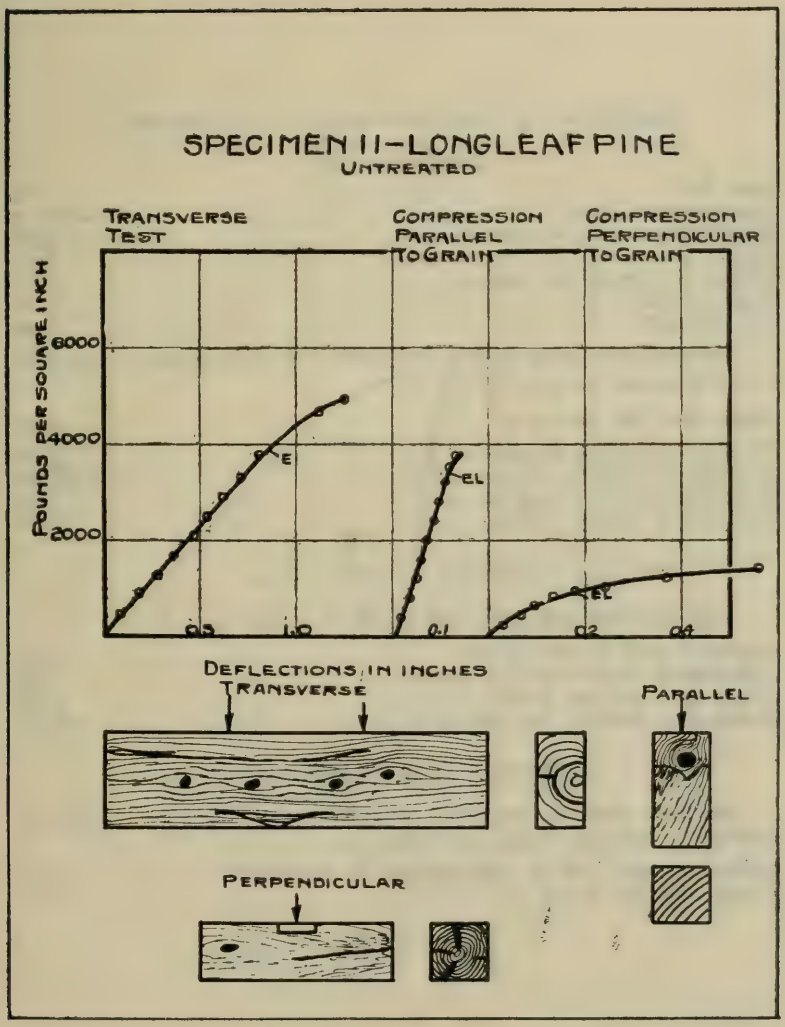
Specimen straight grained, with one large knot near one end. Failure was by crushing near the knot, which diverted the fracture.

Maximum load, lbs. per sq. in	3,995
Deflection at maximum load, inches	0.176
Elastic limit, lbs. per sq. in	3,400
Modulus of elasticity, lbs. per sq. in	343,960

Compression Perpendicular to Grain.

Specimen had several large knots and was very cross-grained. Failed by splitting horizontally at one end.

Deflection under load of 1,453 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	900


SPECIMEN 11—LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
E
EL
EL
0.3
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 12—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.40x7.19
Weight, lbs. per cu. ft., treated	50.6
Weight, lbs. per cu. ft., untreated	39.1
Weight, lbs. per cu. ft., increase	11.5
Rings, per inch	17
Sap, per cent	20

Specimen was very knotty and showed a heart shake at one end. Failed in simple tension.

Elastic limit, lbs. per sq. in.	4,200
Modulus of rupture, lbs. per sq. in.	5,560
Modulus of elasticity, lbs. per sq. in.	1,395,000
Horizontal shear, lbs. per sq. in.	439
Deflection at failure, inches	1.78

Compression Parallel to Grain.

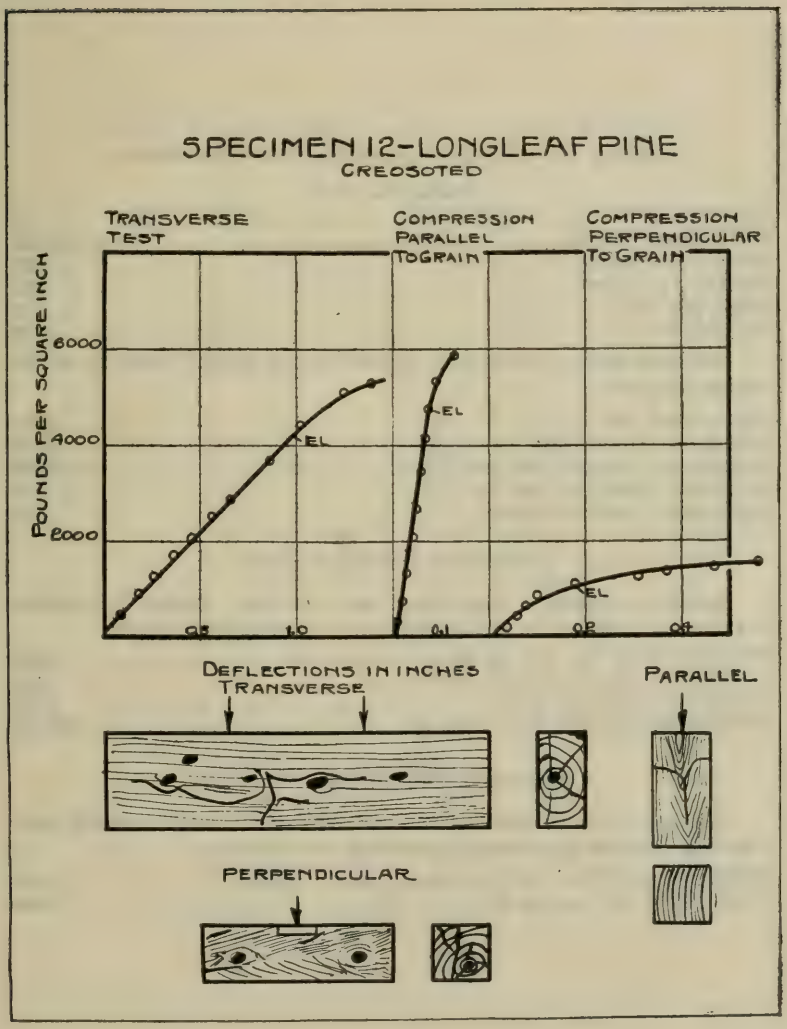
This specimen was clear, and failed by wedge split.

Maximum load, lbs. per sq. in.	5,829
Deflection at maximum load, inches	0.136
Elastic limit, lbs. per sq. in.	4,700
Modulus of elasticity, lbs. per sq. in.	707,410

Compression Perpendicular to Grain.

Specimen showed two large solid knots on one side. Failed by splitting horizontally from one end.

Deflection under load of 1,584 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,100


SPECIMEN 12-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
0.5
1.0
0.1
0.2
0.3
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 13—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.25
Weight, lbs. per cu. ft	38.8
Moisture, per cent	15.3
Rings, per inch	15
Sap, per cent	10

Specimen knotty and showed several dry rot spots. Failed in simple tension at center.

Elastic limit, per sq. in	3,700
Modulus of rupture, lbs. per sq. in	3,670
Modulus of elasticity, lbs. per sq. in	1,310,000
Horizontal shear, lbs. per sq. in	318
Deflection at failure, inches	0.92

Compression Parallel to Grain.

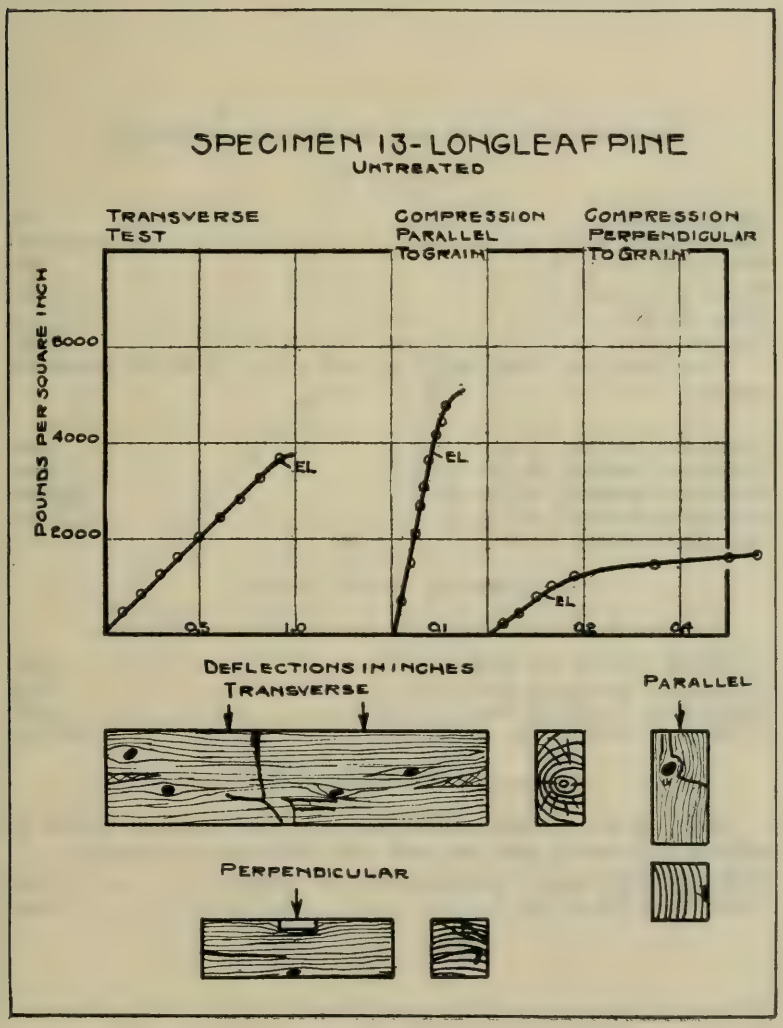
Specimen showed a large knot near one end. Failed by splitting to knot and shearing to one side, the knot diverting the fracture.

Maximum load, lbs. per sq. in	4,806
Deflection at maximum load, inches	0.109
Elastic limit, lbs. per sq. in	3,800
Modulus of elasticity, lbs. per sq. in	568,100

Compression Perpendicular to Grain.

Piece was slightly cracked on one side, and straight grained with some sap. Failed by splitting horizontally near one end.

Deflection under load of 1,714 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	900


SPECIMEN 13- LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
.05
1.00
.01
.02
.04
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 14—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.37x7.44
Weight, lbs. per cu. ft.	38.9
Moisture, per cent	17.5
Rings, per inch	12
Sap, per cent	None

One large knot near center on one side. Failed in splintering tension.

Elastic limit, lbs. per sq. in	4,400
Modulus of rupture, lbs. per sq. in	4,920
Modulus of elasticity, lbs. per sq. in	1,427,000
Horizontal shear, lbs. per sq. in	390
Deflection at failure, inches	1.14

Compression Parallel to Grain.

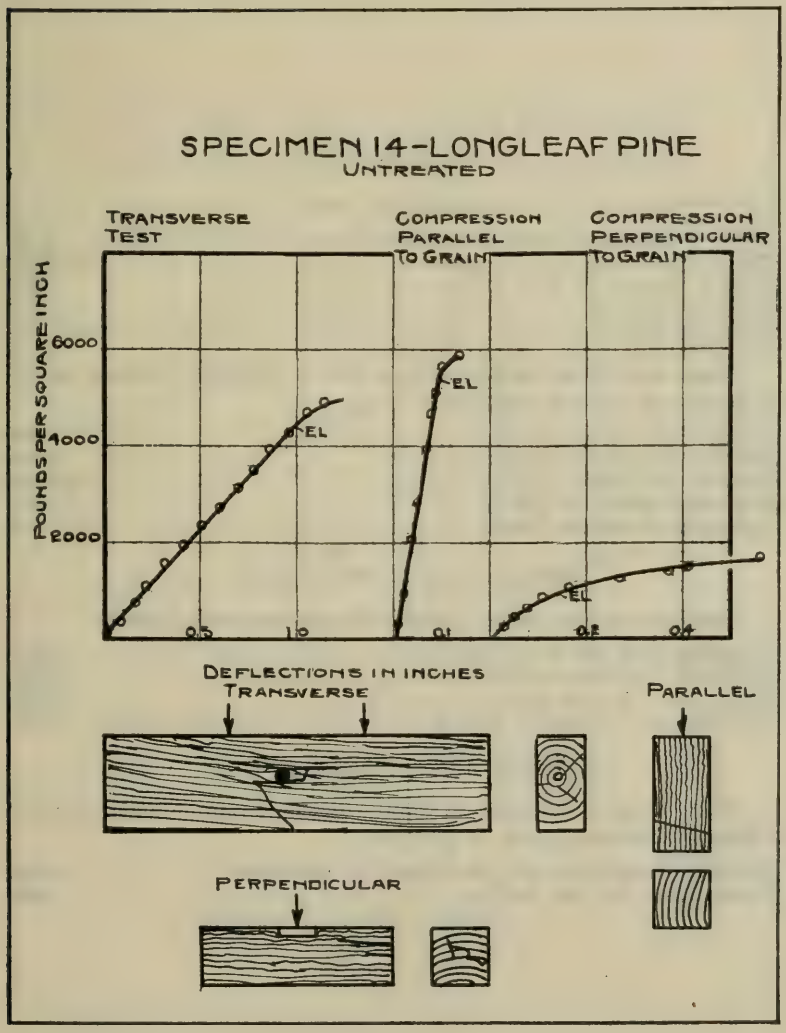
Specimen showed no defects. Sheared across near the bottom.

Maximum load, lbs. per sq. in	5,880
Deflection at maximum load, inches	0.138
Elastic limit, lbs. per sq. in	5,400
Modulus of elasticity, lbs. per sq. in	619,110

Compression Perpendicular to Grain.

Specimen was straight grained and free from sapwood. Failed by splitting horizontally near one end, split following year rings.

Deflection under load, of 1,662 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,000


SPECIMEN 14-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 15—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.20x7.20
Weight, lbs. per cu. ft	46.2
Moisture, per cent	18.4
Rings, per inch	7
Sap, per cent	1

Many small knots showed on one side of specimen. Failure caused by horizontal shear in two planes.

Elastic limit, lbs. per sq. in	1,800
Modulus of rupture, lbs. per sq. in	4,870
Modulus of elasticity, lbs. per sq. in	1,918,000
Horizontal shear, lbs. per sq. in	367
Deflection at failure, inches	1.6

Compression Parallel to Grain.

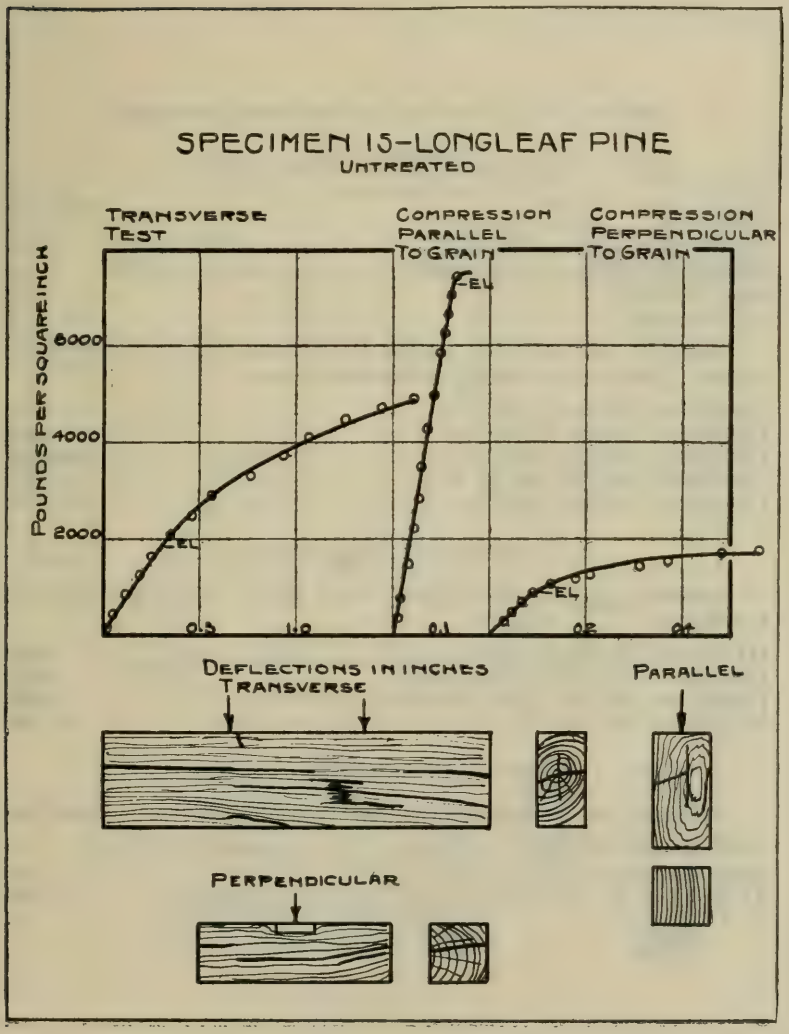
Specimen had no defects. Failed by splitting and crushing.

Maximum load, lbs. per sq. in	7,410
Deflection at maximum load, inches	0.131
Elastic limit, lbs. per sq. in	7,300
Modulus of elasticity, lbs. per sq. in	674,000

Compression Perpendicular to Grain.

Split across one corner of piece. Specimen was straight grained. Failed by horizontal split at one end.

Deflection under load of 1,780 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	900


SPECIMEN 15–LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
4000
2000
EL
EL
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 16—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.38x7.55
Weight, lbs. per cu. ft., treated	51.8
Weight, lbs. per cu. ft., untreated	42.3
Weight, lbs. per cu. ft., increase	9.5
Rings, per inch	7
Sap, per cent	1

Specimen was top timber having several large knots and was cross-grained. Failure was caused by horizontal shear.

Elastic limit, lbs. per sq. in.	3,900
Modulus of rupture, lbs. per sq. in.	4,406
Modulus of elasticity, lbs. per sq. in.	1,690,000
Horizontal shear, lbs. per sq. in.	346
Deflection at failure, inches	1.03

Compression Parallel to Grain.

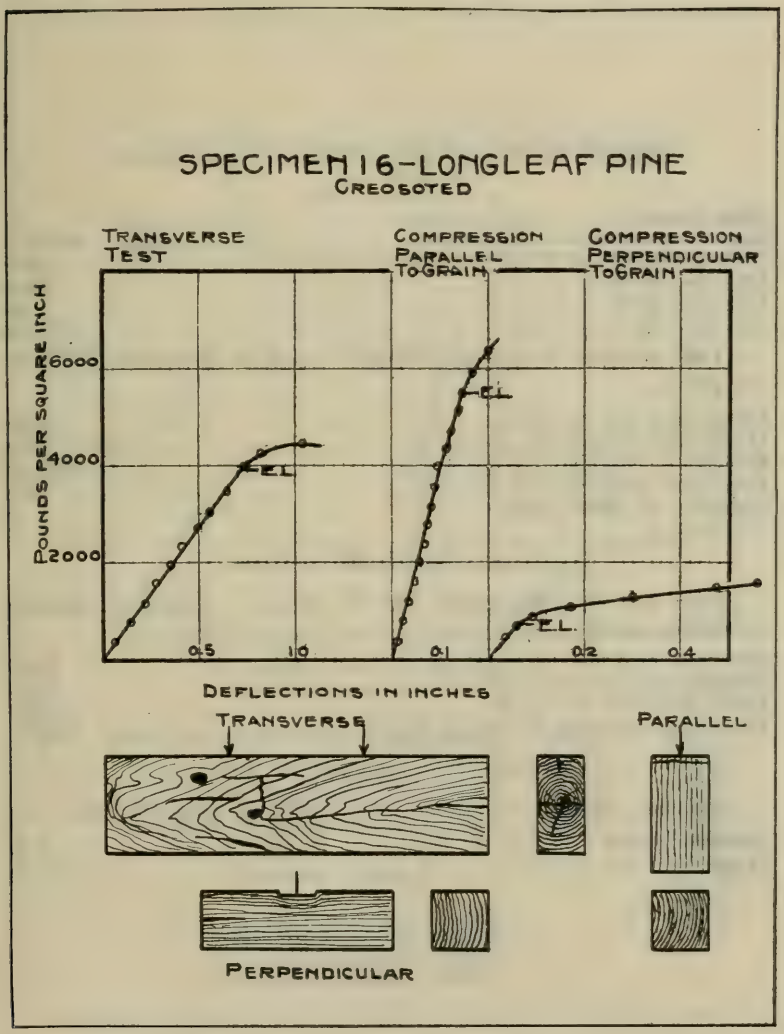
Specimen was cross-grained and failure showed crushing at both top and bottom.

Maximum load, lbs. per sq. in.	6,263
Deflection at maximum load, inches	0.152
Elastic limit, lbs. per sq. in.	5,500
Modulus of elasticity, lbs. per sq. in.	474,000

Compression Perpendicular to Grain.

Specimen was straight-grained and failed by splitting to ends and crushing under plate.

Deflection under a load of 1,548 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	800


SPECIMEN 16-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
E.L.
E.L.
E.L.
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 17—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.2x7.2
Weight, lbs. per cu. ft	43.8
Moisture, per cent	20.4
Rings, per inch	13
Sap, per cent	None

This specimen was a clear stick. Failed in horizontal shear in two planes.

Elastic limit, lbs. per sq. in	2,800
Modulus of rupture, lbs. per sq. in	3,880
Modulus of elasticity, lbs. per sq. in	1,882,000
Horizontal shear, lbs. per sq. in	410
Deflection at failure, inches	1.38

Compression Parallel to Grain.

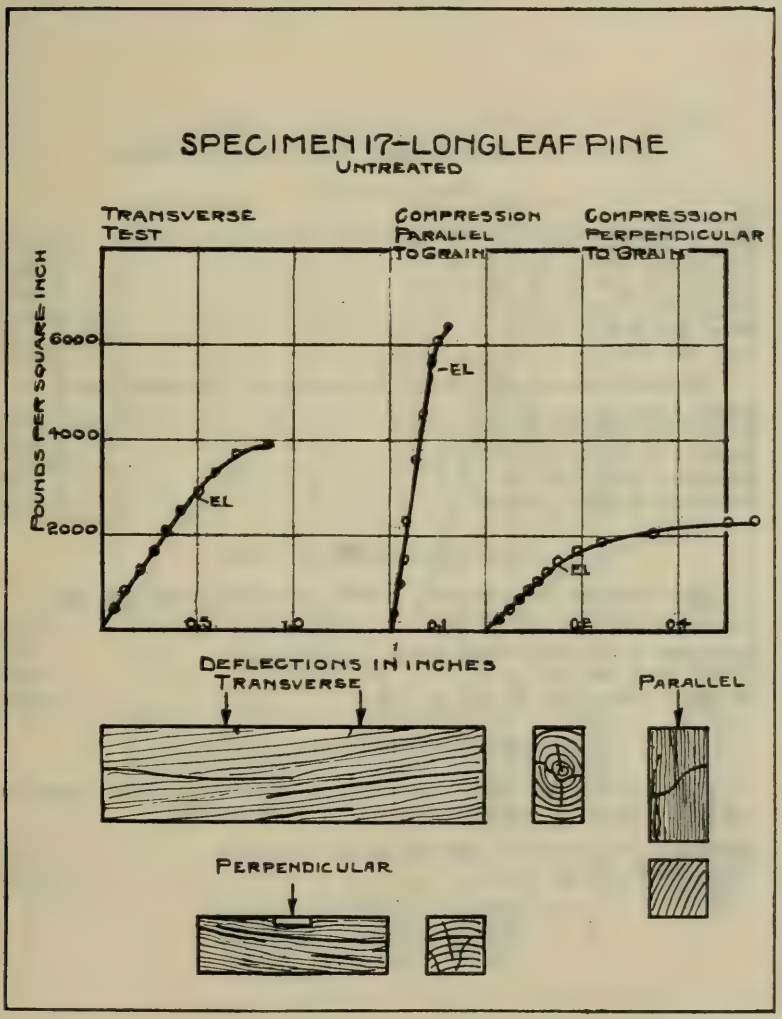
Piece was straight-grained, with no defects. Failed by shearing across the center.

Maximum load, lbs. per sq. in	6,397
Deflection at maximum load, inches	0.125
Elastic limit, lbs. per sq. in	5,600
Modulus of elasticity, lbs. per sq. in	840,000

Compression Perpendicular to Grain.

Specimen was cracked on one side. Failed in horizontal shear.

Deflection under load of 2,363 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,400


SPECIMEN 17—LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 18—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x7.0
Weight, lbs. per cu. ft., treated	61.8
Weight, lbs. per cu. ft., untreated	40.5
Weight, lbs. per cu. ft., increase	21.3
Rings, per inch	10
Sap, per cent	None

The piece showed no defects. Failure was by horizontal shear.

Elastic limit, lbs. per sq. in.	5,000
Modulus of rupture, lbs. per sq. in.	5,050
Modulus of elasticity, lbs. per sq. in.	1,749,000
Horizontal shear, lbs. per sq. in.	388
Deflection at failure, inches	0.93

Compression Parallel to Grain.

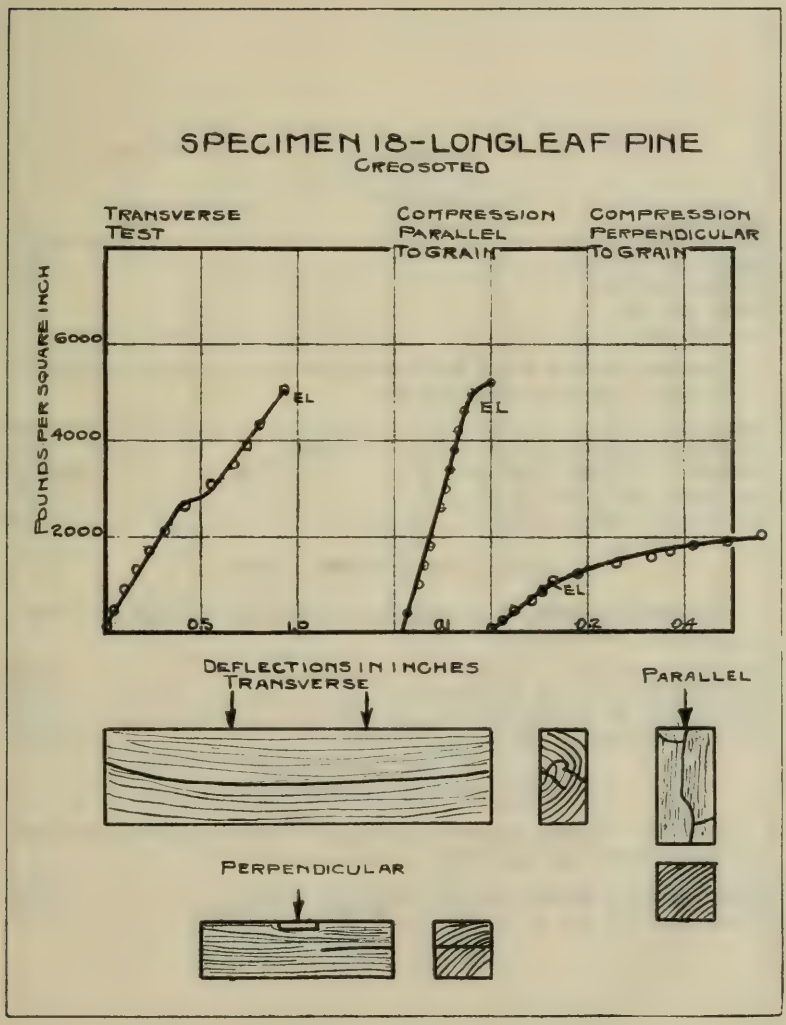
Piece was free from defects. Failed by crushing and splitting.

Maximum load, lbs. per sq. in.	5,279
Deflection at maximum load, inches	0.2
Elastic limit, lbs. per sq. in.	4,800
Modulus of elasticity, lbs. per sq. in.	364,500

Compression Perpendicular to Grain.

Specimen showed fairly straight grain and several light cracks on one side. Failed by splitting horizontally from one end.

Deflection under load of 2,028 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,100


SPECIMEN 18-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
0.5
1.0
.01
.02
.04
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 19—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.11
Weight, lbs. per cu. ft.	45.8
Moisture, per cent	8.5
Rings, per inch	21
Sap, per cent	3

Specimen showed a few small pin knots and a pitch pocket near top on one side. Failed in simple tension.

Elastic limit, lbs. per sq. in.	2,000
Modulus of rupture, lbs. per sq. in.	3,820
Modulus of elasticity, lbs. per sq. in.	1,820,000
Horizontal shear, lbs. per sq. in.	384
Deflection at failure, inches	1.28

Compression Parallel to Grain.

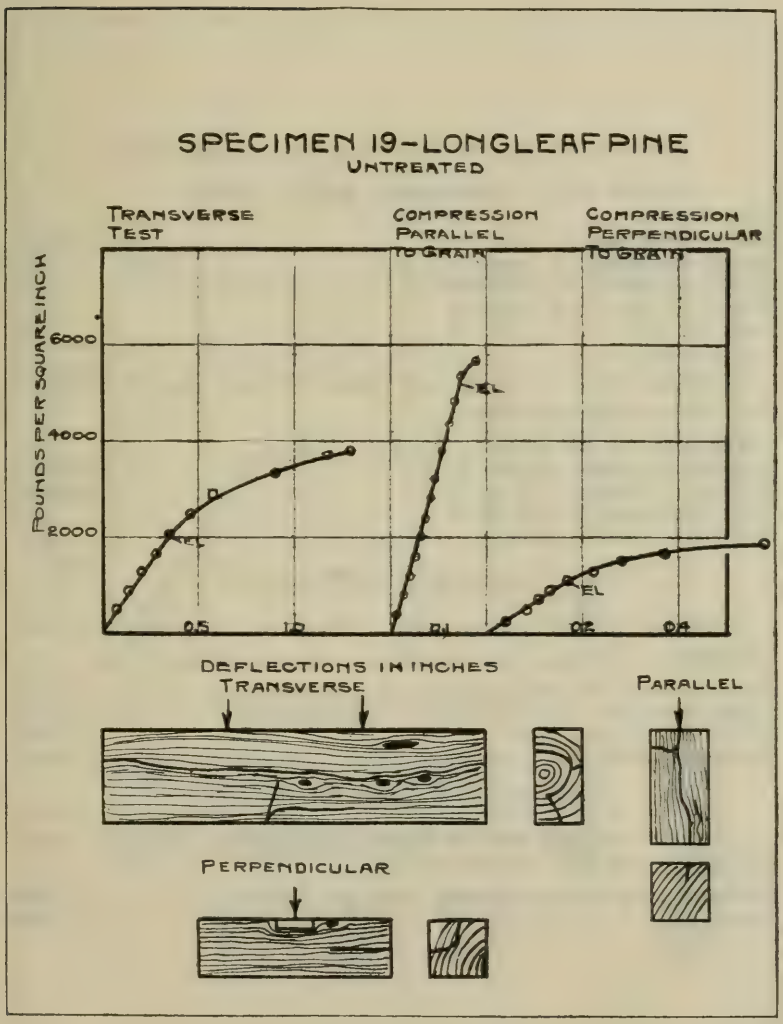
Specimen was slightly cross-grained. Failed by splitting and crushing near top and bottom.

Maximum load, lbs. per sq. in.	5,659
Deflection at maximum load, inches	0.162
Elastic limit, lbs. per sq. in.	5,200
Modulus of elasticity, lbs. per sq. in.	451,300

Compression Perpendicular to Grain.

Specimen showed sapwood at ends. Failed by splitting vertically and horizontally near one end.

Deflection under load of 1,891 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,100


SPECIMEN 19—LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
P
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 20—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.25
Weight, lbs. per cu. ft., treated	52.1
Weight, lbs. per cu. ft., untreated	49.6
Weight, lbs. per cu. ft., increase	2.5
Rings, per inch	21
Sap, per cent	3

Specimen had heart shake and checks. Failure was by horizontal shear and cross-grained tension.

Elastic limit, lbs. per sq. in	4,325
Modulus of rupture, lbs. per sq. in	4,477
Modulus of elasticity, lbs. per sq. in	1,875,000
Horizontal shear, lbs. per sq. in	350
Deflection at failure, inches	0.72

Compression Parallel to Grain.

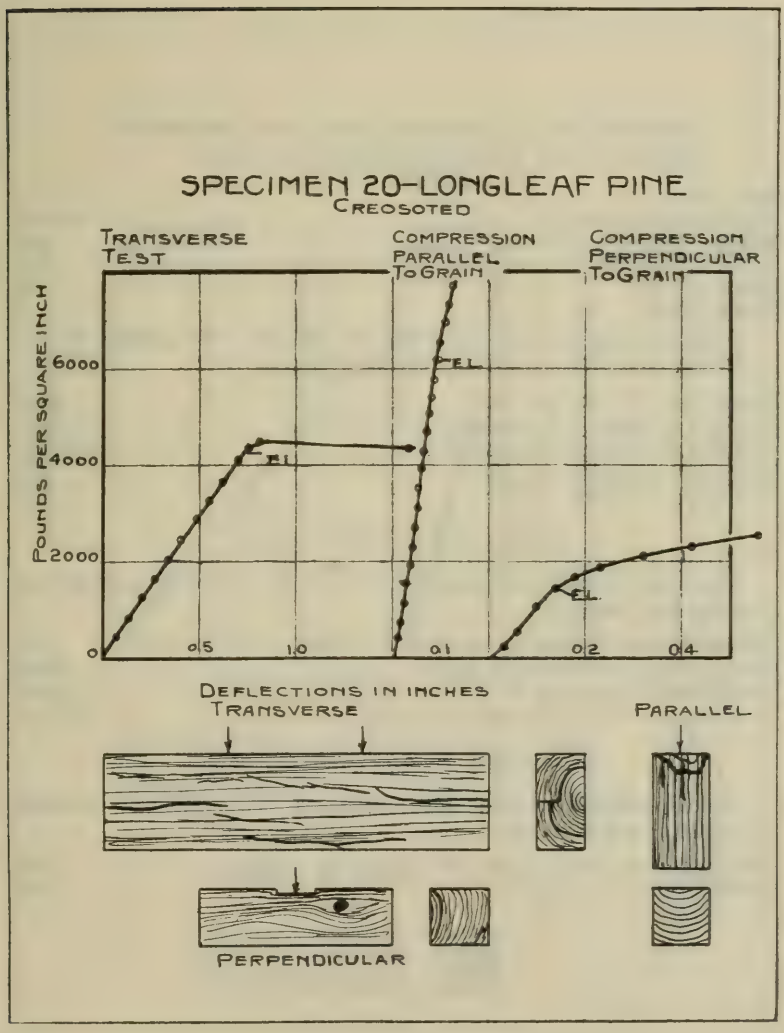
Stick was slightly cross-grained. Failure was by wedge shear and splitting.

Maximum load, lbs. per sq. in	7,721
Deflection at maximum load, inches	0,128
Elastic limit, lbs. per sq. in	6,200
Modulus of elasticity, lbs. per sq. in	835,000

Compression Perpendicular to Grain.

Specimen had bad shake at bottom and one knot. Failed by crushing under plate and splitting to end.

Deflection under load of 2,250 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,400


SPECIMEN 20—LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
0
EL
EL
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 21—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.12x7.05
Weight, lbs. per cu. ft.	38.9
Moisture, per cent	16.6
Rings, per inch	12
Sap, per cent	10

The specimen had two pin knots on one side. The failure was by horizontal shear, the knots diverting the fracture.

Elastic limit, lbs. per sq. in.	5,000
Modulus of rupture, lbs. per sq. in.	6,800
Modulus of elasticity, lbs. per sq. in.	1,517,000
Horizontal shear, lbs. per sq. in.	528
Deflection at failure, inches	1.75

Compression Parallel to Grain.

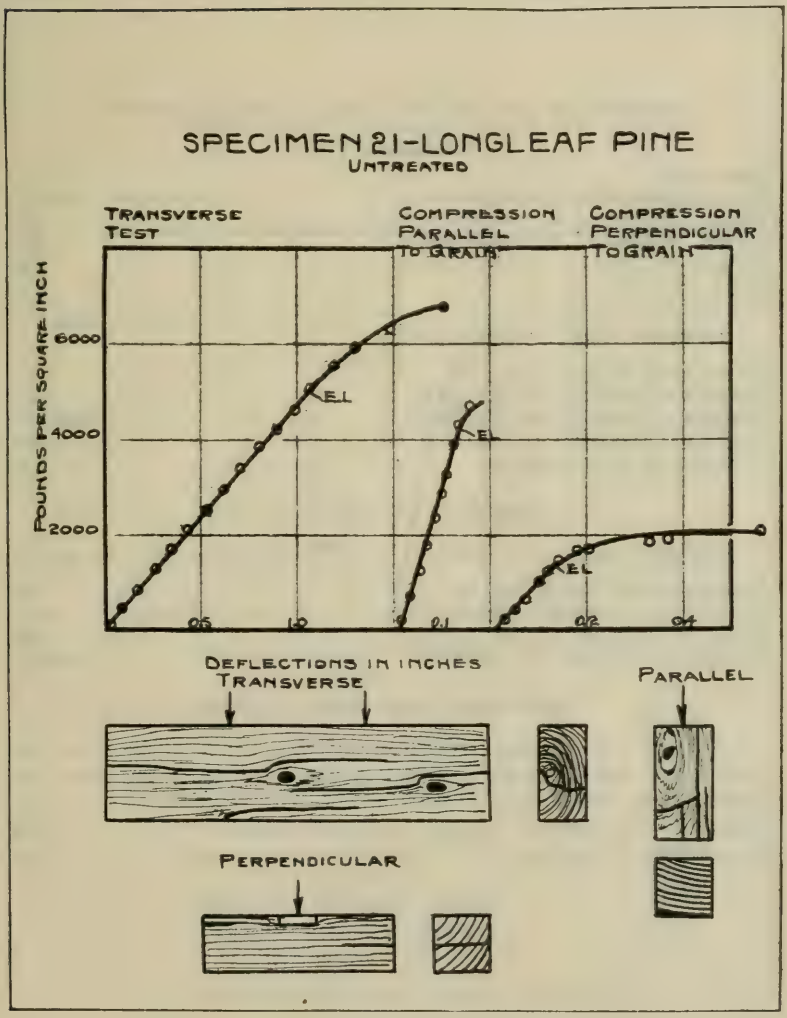
Specimen showed some sapwood at the ends. Failed by splitting and crushing near center.

Maximum load, lbs. per sq. in.	4,668
Deflection at maximum load, inches	0.155
Elastic limit, lbs. per sq. in.	4,200
Modulus of elasticity, lbs. per sq. in.	385,000

Compression Perpendicular to Grain.

Straight-grained specimen, with sapwood at ends. Failed by splitting horizontally near one end.

Deflection under load of 2,051 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,500


SPECIMEN 21-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
E.L
E.L
E.L
.05
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 22—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x7.1
Weight, lbs. per cu. ft., treated	55.2
Weight, lbs. per cu. ft., untreated	42.2
Weight, lbs. per cu. ft., increase	13.0
Rings, per inch	12
Sap, per cent	10

Specimen failed in brittle tension.

Elastic limit, lbs. per sq. in	5,400
Modulus of rupture, lbs. per sq. in	5,410
Modulus of elasticity, lbs. per sq. in	1,428,000
Horizontal shear, lbs. per sq. in	416
Deflection at failure, inches	1.24

Compression Parallel to Grain.

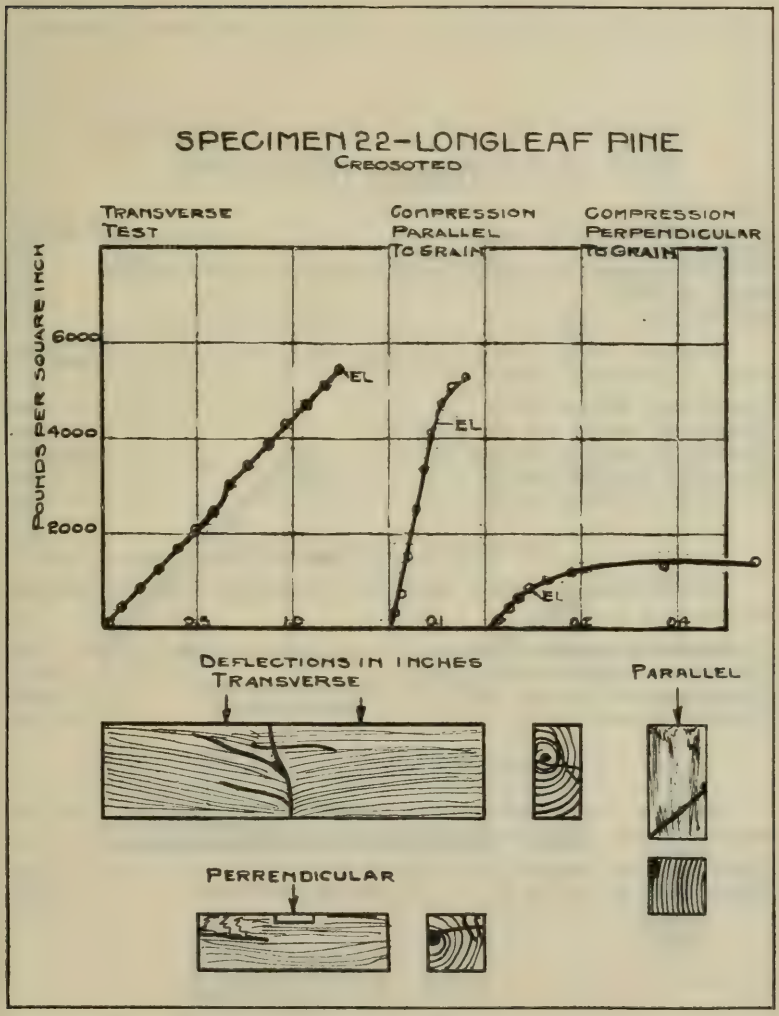
Specimen showed no defects. Failed by shearing near the bottom.

Maximum load, lbs. per sq. in	5,228
Deflection at maximum load, inches	0.161
Elastic limit, lbs. per sq. in	4,300
Modulus of elasticity, lbs. per sq. in	556,850

Compression Perpendicular to Grain.

This specimen showed a crack running the length of the piece and three inches below the top. Failure was by opening up this crack and splitting horizontally from one end.

Deflection under load of 1,404 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	900


SPECIMEN 22-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERREMDICULAR

SPECIMEN NO. 23—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.50x7.07
Weight, lbs. per cu. ft.	45.8
Moisture, per cent	19.0
Rings, per inch	10.0
Sap, per cent	1.0

Specimen showed small amount of pitch and a few small knots. Failed in horizontal shear.

Elastic limit, lbs. per sq. in.	3,800
Modulus of rupture, lbs. per sq. in.	4,050
Modulus of elasticity, lbs. per sq. in.	1,254,000
Horizontal shear, lbs. per sq. in.	322
Deflection at failure, inches	0.97

Compression Parallel to Grain.

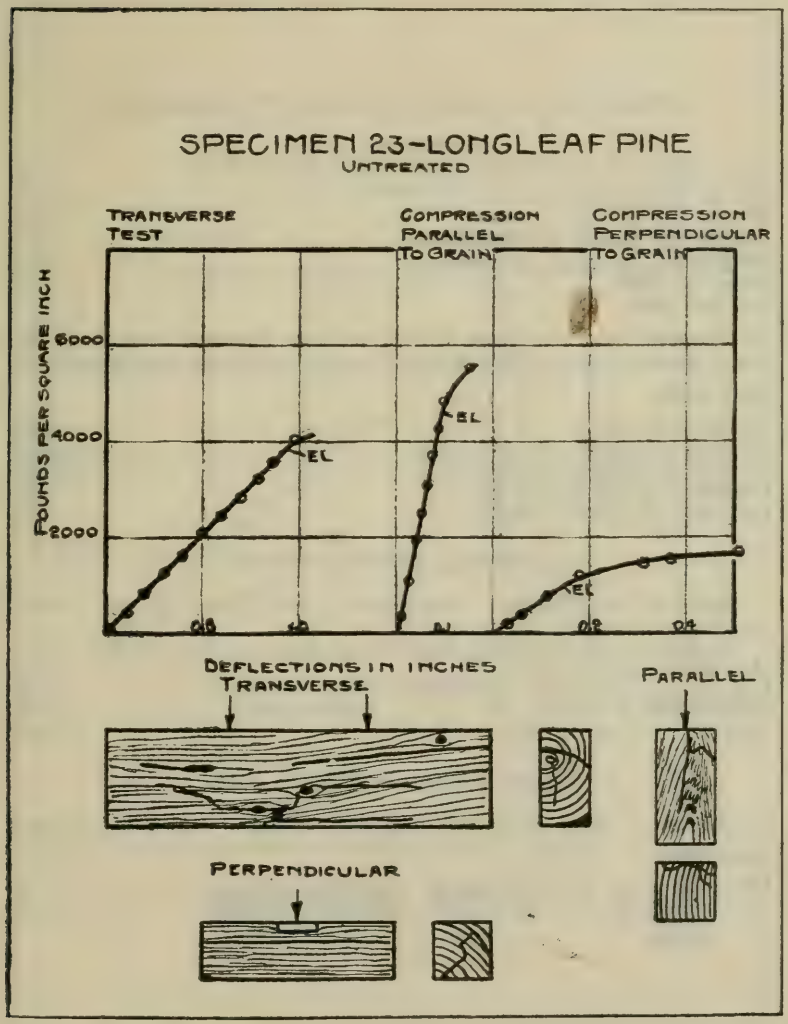
Specimen was straight-grained, with no defects. Failed by splitting and crushing near top.

Maximum load, lbs. per sq. in.	5,569
Deflection at maximum load, inches	0.155
Elastic limit, lbs. per sq. in.	4,600
Modulus of elasticity, lbs. per sq. in.	551,310

Compression Perpendicular to Grain.

Specimen was straight-grained, but full of cracks. Failure was by horizontal shear along an old crack.

Deflection under load of 1,692 lbs. per sq. in., inches	0.55
Elastic limit, lbs. per sq. in.	1,000


SPECIMEN 23-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
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EL
EL
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 24—LONG-LEAF YELLOW PINE. (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.75x7.18
Weight, lbs. per cu. ft., treated	52.2
Weight, lbs. per cu. ft., untreated	37.2
Weight, lbs. per cu. ft., increase	15.0
Rings, per inch	10
Sap, per cent	1

Specimen had bad heart shake, but was otherwise free from defects. Failure was by cross-grained tension and horizontal shear along heart shake.

Elastic limit, lbs. per sq. in	3,500
Modulus of rupture, lbs. per sq. in	4,850
Modulus of elasticity, lbs. per sq. in	1,206,000
Horizontal shear, lbs. per sq. in	392
Deflection at failure, inches	1.39

Compression Parallel to Grain.

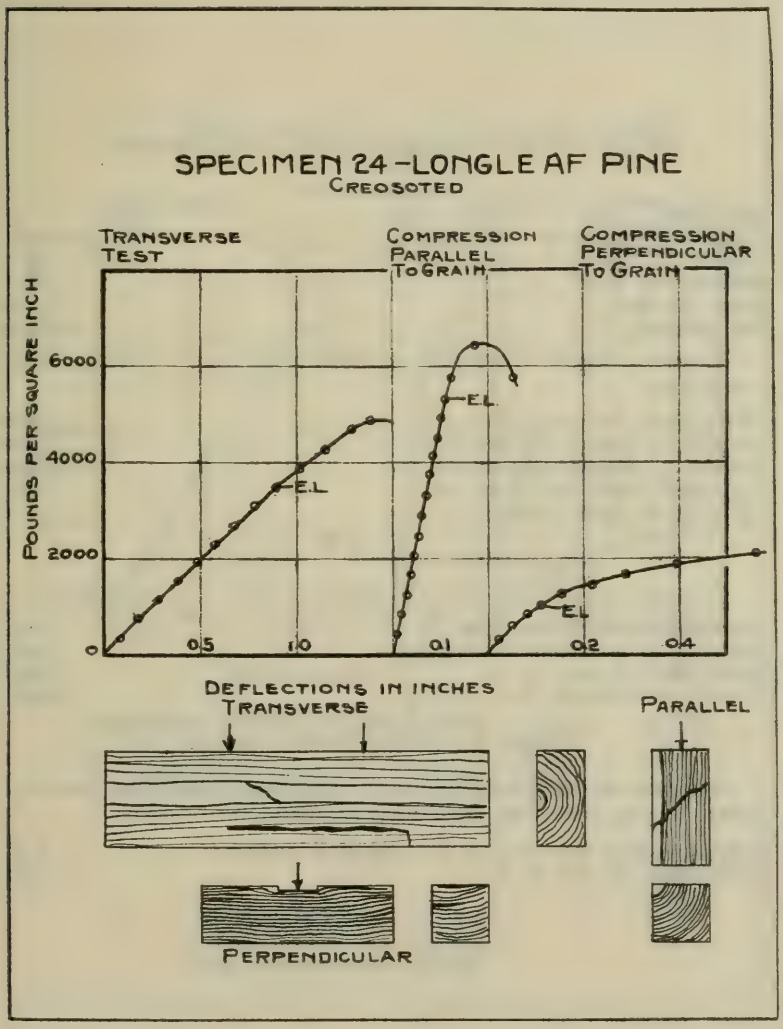
Specimen was slightly cross-grained, with shake in one corner. Failed by crushing at center.

Maximum load, lbs. per sq. in	6,410
Deflection at maximum load, inches	0.172
Elastic limit, lbs. per sq. in	5,081
Modulus of elasticity, lbs. per sq. in	584,400

Compression Perpendicular to Grain.

Stick had shake along side and knot at side. Failed by crushing under plate.

Deflection under load of 2,084 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,000


SPECIMEN 24 - LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
0
E.L.
E.L.
E.L.
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 25—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x7.11
Weight, lbs. per cu. ft.	42.4
Moisture, per cent	15.1
Rings, per inch	19
Sap, per cent	None

Specimen showed a few small pin knots on one side. Failed by horizontal shear.

Elastic limit, lbs. per sq. in	5,800
Modulus of rupture, lbs. per sq. in	6,280
Modulus of elasticity, lbs. per sq. in	1,876,000
Horizontal shear, lbs. per sq. in	483
Deflection at failure, inches	1.14

Compression Parallel to Grain.

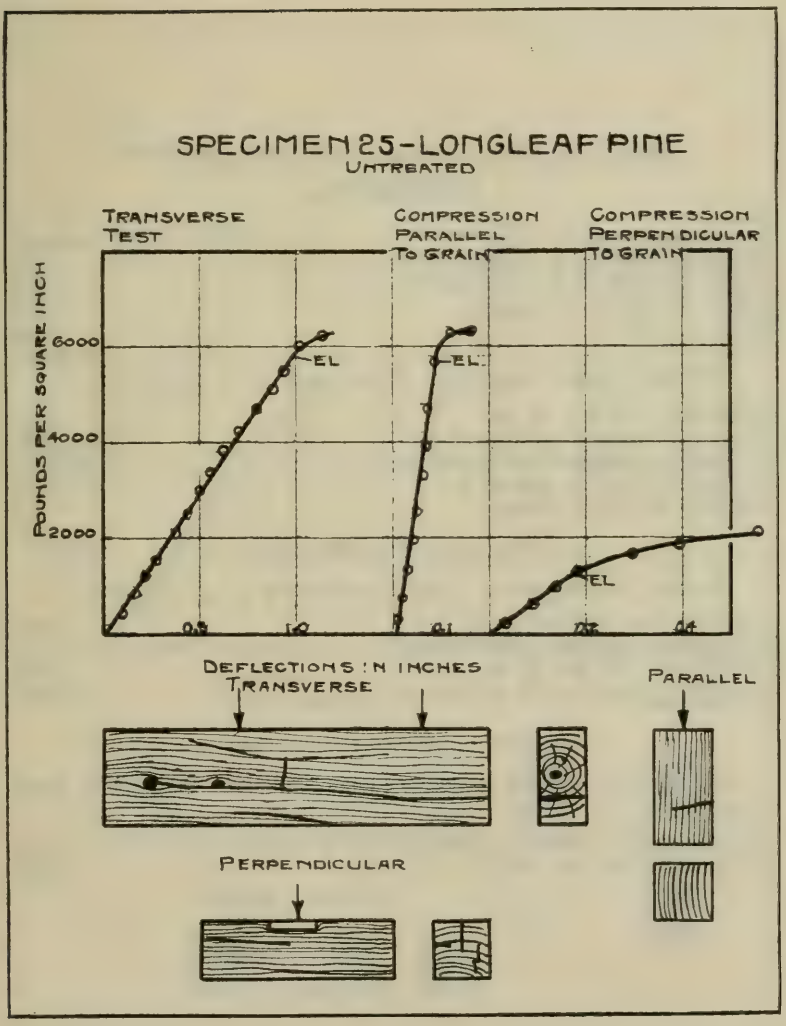
Specimen showed no defects. Failed by crushing near the bottom.

Maximum load, lbs. per sq. in	6,353
Deflection at maximum load, inches	0.165
Elastic limit, lbs. per sq. in	5,700
Modulus of elasticity, lbs. per sq. in	758,720

Compression Perpendicular to Grain.

Specimen showed a bad crack and considerable sapwood on one side. Failure was by horizontal shear along the crack.

Deflection under load of 2,120 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,200


SPECIMEN 25-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
0.3
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 26—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.1x7.15
Weight, lbs. per cu. ft., treated	57.5
Weight, lbs. per cu. ft., untreated	46.5
Weight, lbs. per cu. ft., increase	11.0
Rings, per inch	19
Sap, per cent	None

This piece showed no defects. Failure was by horizontal shear.

Elastic limit, lbs. per sq. in	4,600
Modulus of rupture, lbs. per sq. in	4,880
Modulus of elasticity, lbs. per sq. in	1,600,000
Horizontal shear, lbs. per sq. in	378
Deflection at failure, inches	1.0

Compression Parallel to Grain.

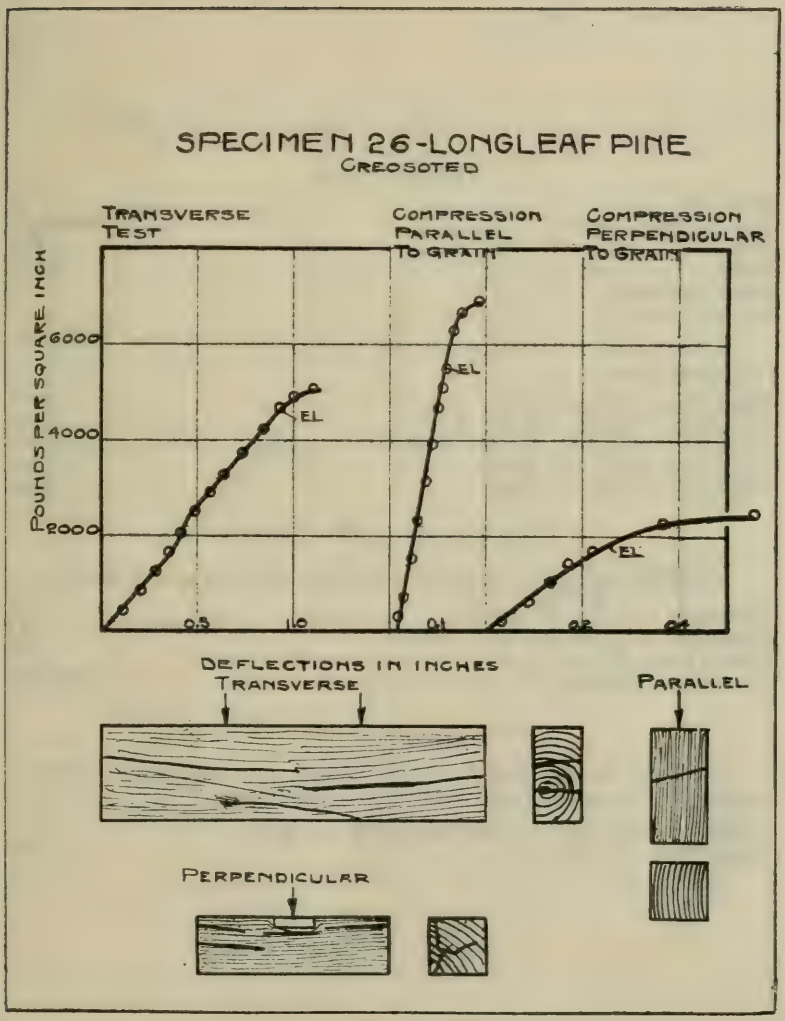
Specimen had no defects. Failed by shearing across the center.

Maximum load, lbs. per sq. in	6,860
Deflection at maximum load, inches	0.185
Elastic limit, lbs. per sq. in	5,800
Modulus of elasticity, lbs. per sq. in	580,000

Compression Perpendicular to Grain.

This specimen showed several cracks on one side. Piece failed along these cracks.

Deflection under load of 2,479 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,800


SPECIMEN 26-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 27—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.22
Weight, lbs. per cu. ft	38.9
Moisture, per cent	16.75
Rings, per inch	8
Sap, per cent	8

Specimen showed small knots and some sapwood on top. Failed by horizontal shear.

Elastic limit, lbs. per sq. in	3,900
Modulus of rupture, lbs. per sq. in	4,500
Modulus of elasticity, lbs. per sq. in	1,505,000
Horizontal shear, lbs. per sq. in	352
Deflection at failure, inches	0.98

Compression Parallel to Grain.

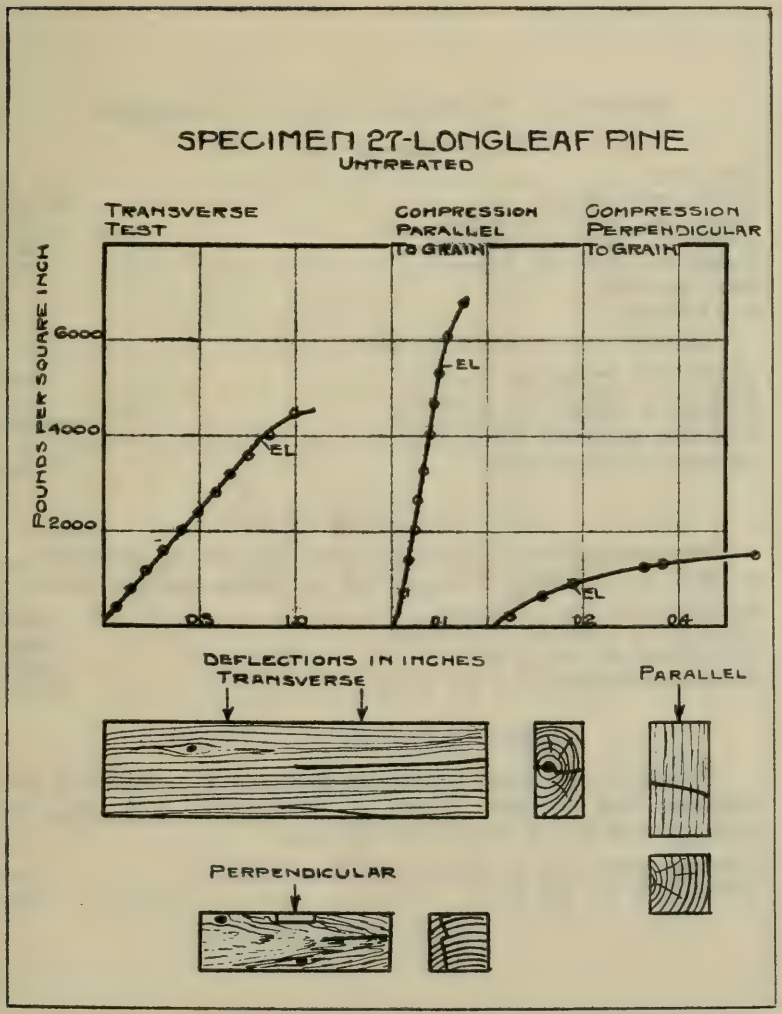
Specimen showed no defects. Failed by shearing across center.

Maximum load, lbs. per sq. in	6,754
Deflection at maximum load, inches	0.15
Elastic limit, lbs. per sq. in	5,500
Modulus of elasticity, lbs. per sq. in	665,500

Compression Perpendicular to Grain.

Specimen showed several small knots and sap on one side. Failed by splitting horizontally at one end.

Deflection under load of 1,466 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	900


SPECIMEN 27-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
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.02
.04
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 28—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.2x7.08
Weight, lbs. per cu. ft., treated	57.8
Weight, lbs. per cu. ft., untreated	44.5
Weight, lbs. per cu. ft., increase	13.3
Rings, per inch	8
Sap, per cent	8

Specimen failed in horizontal shear.

Elastic limit, lbs. per sq. in	3,100
Modulus of rupture, lbs. per sq. in	3,280
Modulus of elasticity, lbs. per sq. in	1,417,000
Horizontal shear, lbs. per sq. in	374
Deflection at failure, inches	0.7

Compression Parallel to Grain.

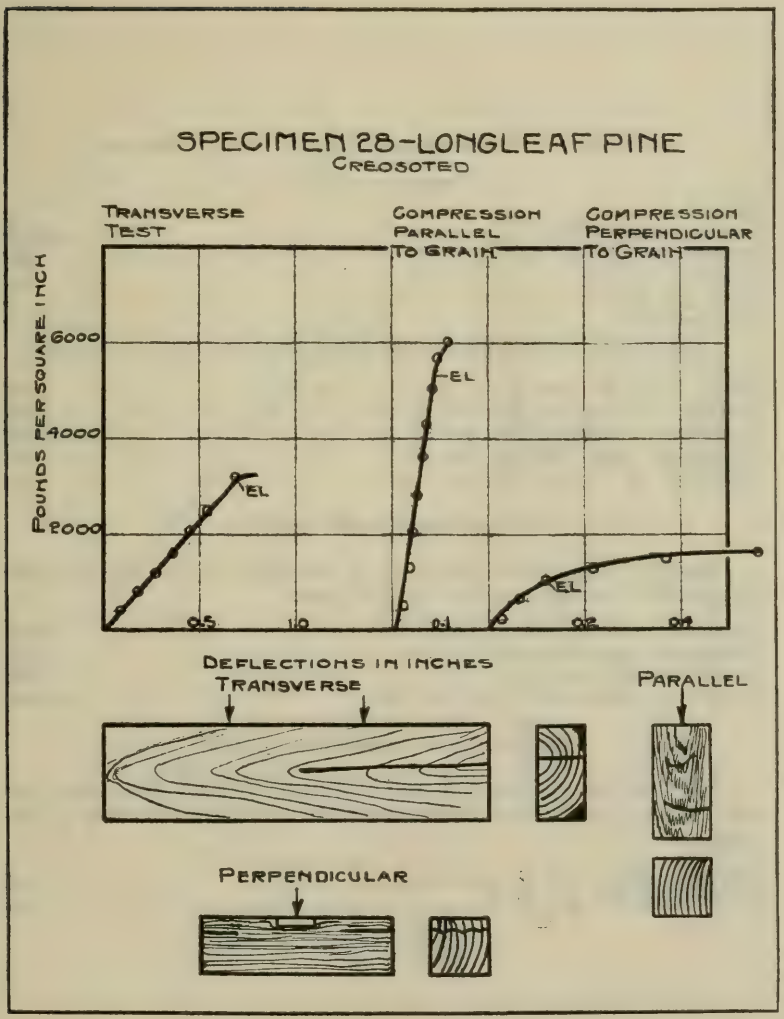
This specimen showed a pitch pocket on one side, but this defect had no effect on the failure, which occurred by crushing near the bottom.

Maximum load, lbs. per sq. in	6,064
Deflection at maximum load, inches	0.118
Elastic limit, lbs. per sq. in	5,300
Modulus of elasticity, lbs. per sq. in	706,660

Compression Perpendicular to Grain.

This piece was straight grained and had a crack one-half inch deep extending along one side. Failure was by horizontal shear along this crack, splitting toward center from both ends.

Deflection under load of 1,626 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,000


SPECIMEN 28-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 20—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.06x6.98
Weight, lbs. per cu. ft.	38.4
Moisture, per cent.	13.5
Rings, per inch	8
Sap, per cent	15

Specimen showed small knots on sides. Failed by horizontal shear.

Elastic limit, lbs. per sq. in.	5,000
Modulus of rupture, lbs. per sq. in.	6,160
Modulus of elasticity, lbs. per sq. in.	1,612,000
Horizontal shear, lbs. per sq. in.	468
Deflection at failure, inches	1.4

Compression Parallel to Grain.

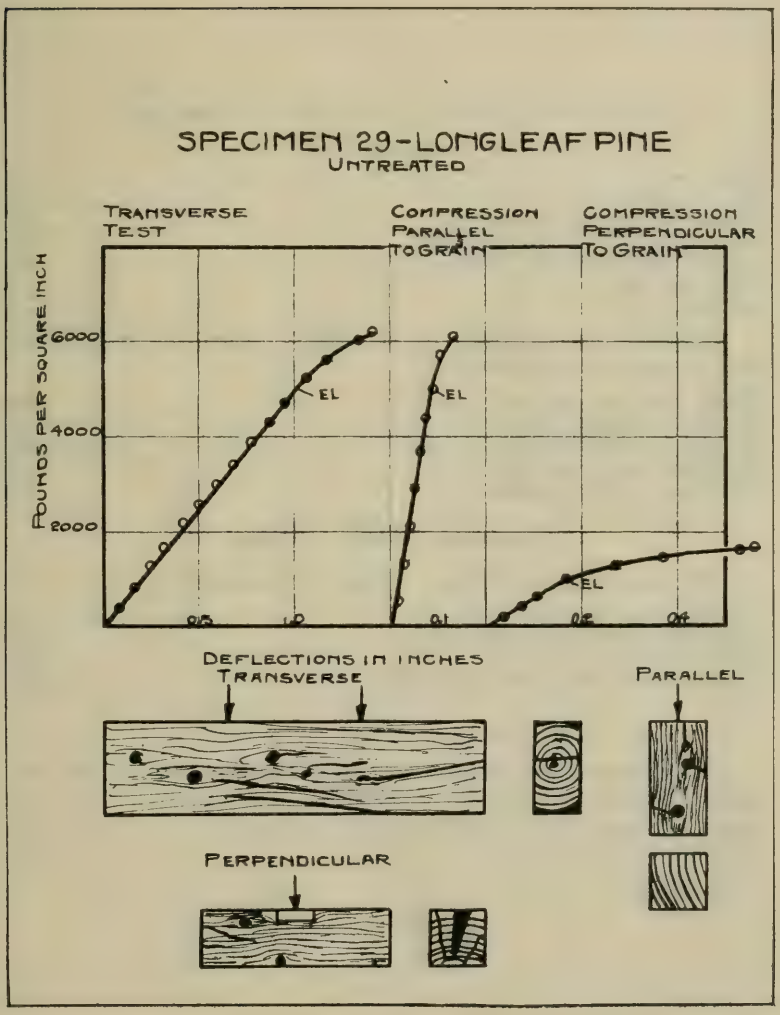
Specimen showed two large knots on one side. Failure was by crushing outward from the knots to sides of piece.

Maximum load, lbs. per sq. in.	6,126
Deflection at maximum load, inches	0.133
Elastic limit, lbs. per sq. in.	5,000
Modulus of elasticity, lbs. per sq. in.	666,000

Compression Perpendicular to Grain.

Specimen showed several knots on side and a large spike knot at one end. Failure was by horizontal shear, but knots had no effect on the fracture.

Deflection under load of 1,724 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,400


SPECIMEN 29-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 30—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.1x7.14
Weight, lbs. per cu. ft., treated	60.5
Weight, lbs. per cu. ft., untreated	41.3
Weight, lbs. per cu. ft., increase	19.2
Rings, per inch	8
Sap, per cent	15

Specimen had a pin knot on one side. Failure was by horizontal shear passing below the knot.

Elastic limit, lbs. per sq. in	4,800
Modulus of rupture, lbs. per sq. in	6,320
Modulus of elasticity, lbs. per sq. in	1,715,000
Horizontal shear, lbs. per sq. in	498
Deflection at failure, inches	1.3

Compression Parallel to Grain.

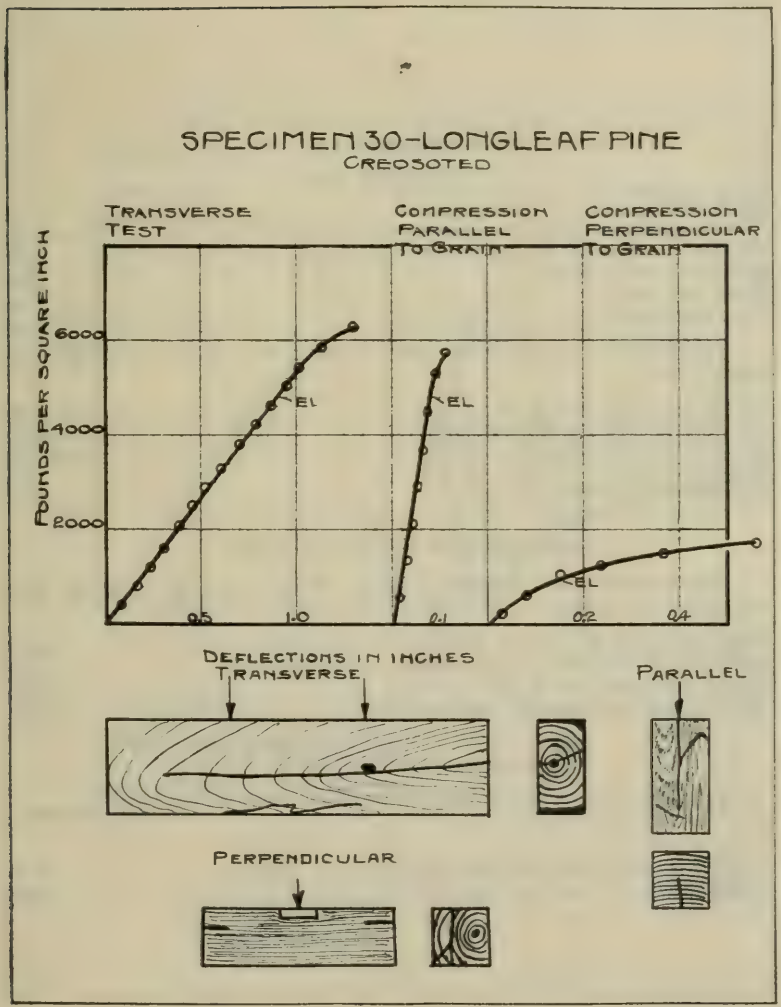
This piece showed no defects. Failed by wedge split.

Maximum load, lbs. per sq. in	5,784
Deflection at maximum load, inches	0.113
Elastic limit, lbs. per sq. in	4,800
Modulus of elasticity, lbs. per sq. in	720,000

Compression Perpendicular to Grain.

This specimen was straight-grained with light cracks on one side. Failed along the cracks, splitting inward from each end.

Deflection under load of 1,636 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,000


SPECIMEN 30-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 31—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x7.17
Weight, lbs. per cu. ft	47.1
Moisture, per cent	16.4
Rings, per inch	14
Sap, per cent	5.0

Specimen had several small knots on one side. Failure was by horizontal shear.

Elastic limit, lbs. per sq. in	4,000
Modulus of rupture, lbs. per sq. in	5,440
Modulus of elasticity, lbs. per sq. in	1,726,000
Horizontal shear, lbs. per sq. in	419
Deflection at failure, inches	1.15

Compression Parallel to Grain.

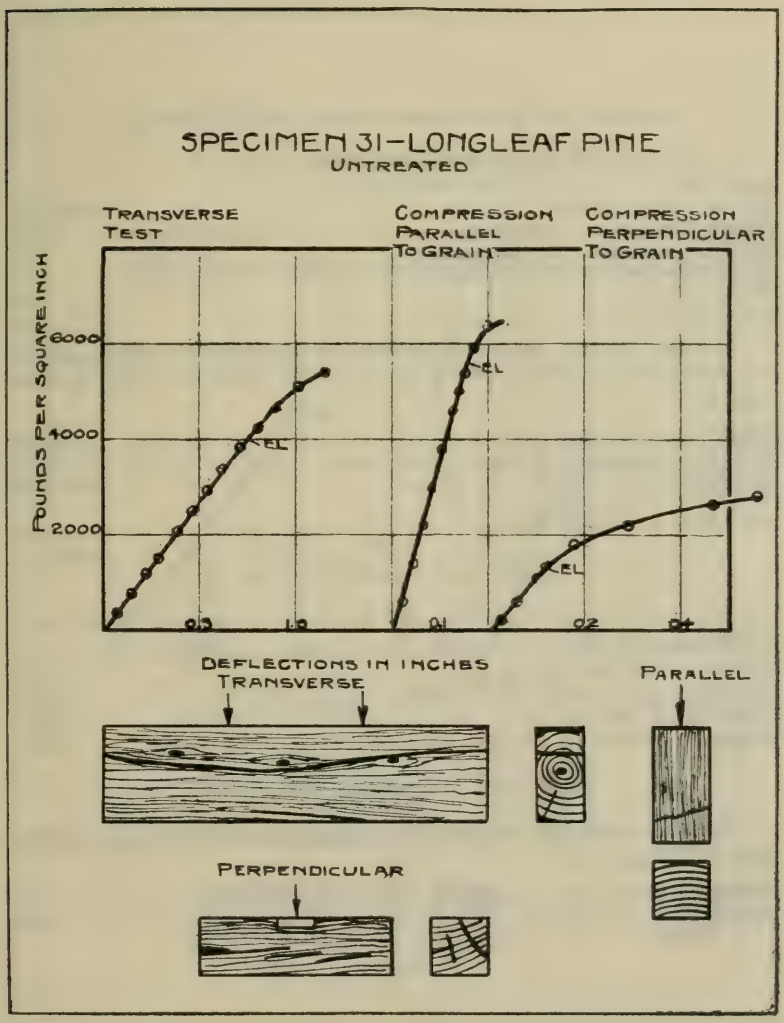
The specimen was without defects. Failure was by shearing near bottom.

Maximum load, lbs. per sq. in	6,253
Deflection at maximum load, inches	0.2
Elastic limit, lbs. per sq. in	5,600
Modulus of elasticity, lbs. per sq. in	423,000

Compression Perpendicular to Grain.

Specimen showed sapwood at both ends. Failed by splitting horizontally.

Deflection under load of 2,824 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,400


SPECIMEN 31—LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 32—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.87x6.94
Weight, lbs. per cu. ft., treated	56.8
Weight, lbs. per cu. ft., untreated	51.3
Weight, lbs. per cu. ft., increase	5.5
Rings, per inch	14
Sap, per cent	5

Specimen full of resin and creosote did not penetrate deeply. Stick was badly cross-grained. Failed by horizontal shear and cross-grained tension.

Elastic limit, lbs. per sq. in.	5,100
Modulus of rupture, lbs. per sq. in.	5,294
Modulus of elasticity, lbs. per sq. in.	1,632,000
Horizontal shear, lbs. per sq. in.	430
Deflection at failure, inches	0.94

Compression Parallel to Grain.

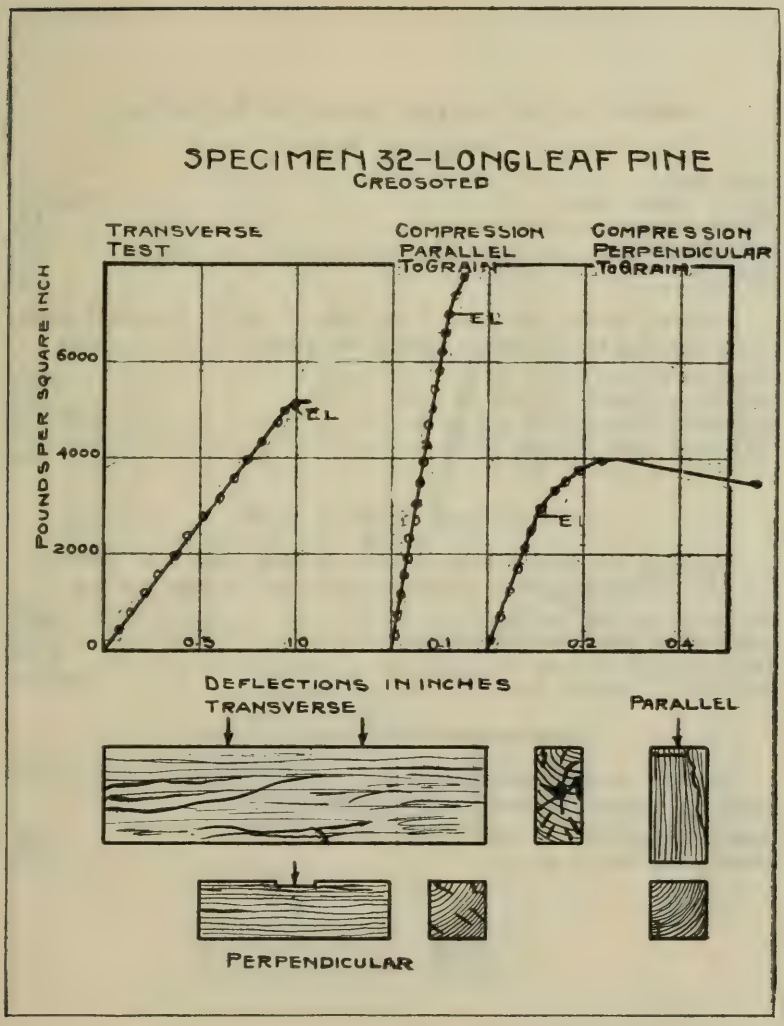
Specimen was cross-grained, and failed by crushing at bottom and splitting to side.

Maximum load, lbs. per sq. in.	7,768
Deflection at maximum load, inches	0.16
Elastic limit, lbs. per sq. in.	7,000
Modulus of elasticity, lbs. per sq. in.	736,000

Compression Perpendicular to Grain.

Specimen was cross-grained with heart shake. Failed by crushing plate into wood.

Deflection under load of 3,480 lbs. per sq. in., inches	0.56
Elastic limit, per sq. in.	2,800


SPECIMEN 32-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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DEFLECTIONS IN INCHES
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PARALLEL
PERPENDICULAR

SPECIMEN NO. 33—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x7.23
Weight, lbs. per cu. ft.	41.8
Moisture, per cent	19.3
Rings, per inch	15
Sap, per cent	1.0

Specimen showed pin knots on one side. Failed in horizontal shear, a knot diverting fracture into a shear in two planes.

Elastic limit, lbs. per sq. in.	4,200
Modulus of rupture, lbs. per sq. in.	5,390
Modulus of elasticity, lbs. per sq. in.	1,600,000
Horizontal shear, lbs. per sq. in.	415
Deflection at failure, inches	1.21

Compression Parallel to Grain.

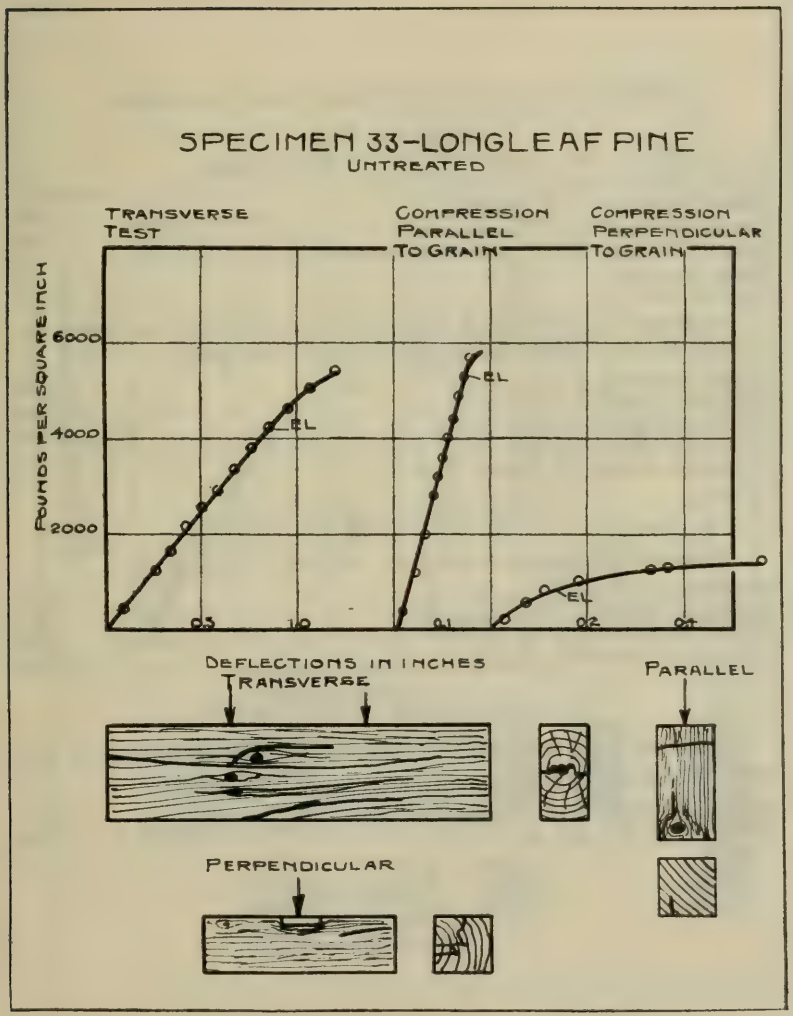
Specimen was straight-grained with one large knot near bottom on one side. Failed by splitting around the knot and crushing near top.

Maximum load, lbs. per sq. in.	5,918
Deflection at maximum load, inches	0.163
Elastic limit, lbs. per sq. in.	5,300
Modulus of elasticity, lbs. per sq. in.	426,000

Compression Perpendicular to Grain.

Specimen was straight-grained with cracks showing on one side. Failed by splitting horizontally near one end.

Deflection under load of 1,464 lbs. per sq. in., inches	0.55
Elastic limit, lbs. per sq. in.	900


SPECIMEN 33-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 34—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.00x7.15
Weight, lbs. per cu. ft., treated	61.4
Weight, lbs. per cu. ft., untreated	45.5
Weight, lbs. per cu. ft., increase	15.9
Rings, per inch	15
Sap, per cent	1

Specimen was thoroughly impregnated with creosote and had a few weather checks. Failure was caused by horizontal shear.

Elastic limit, lbs. per sq. in.	4,425
Modulus of rupture, lbs. per sq. in.	6,049
Modulus of elasticity, lbs. per sq. in.	1,910,000
Horizontal shear, lbs. per sq. in.	465
Deflection at time of failure, inches	0.74

Compression Parallel to Grain.

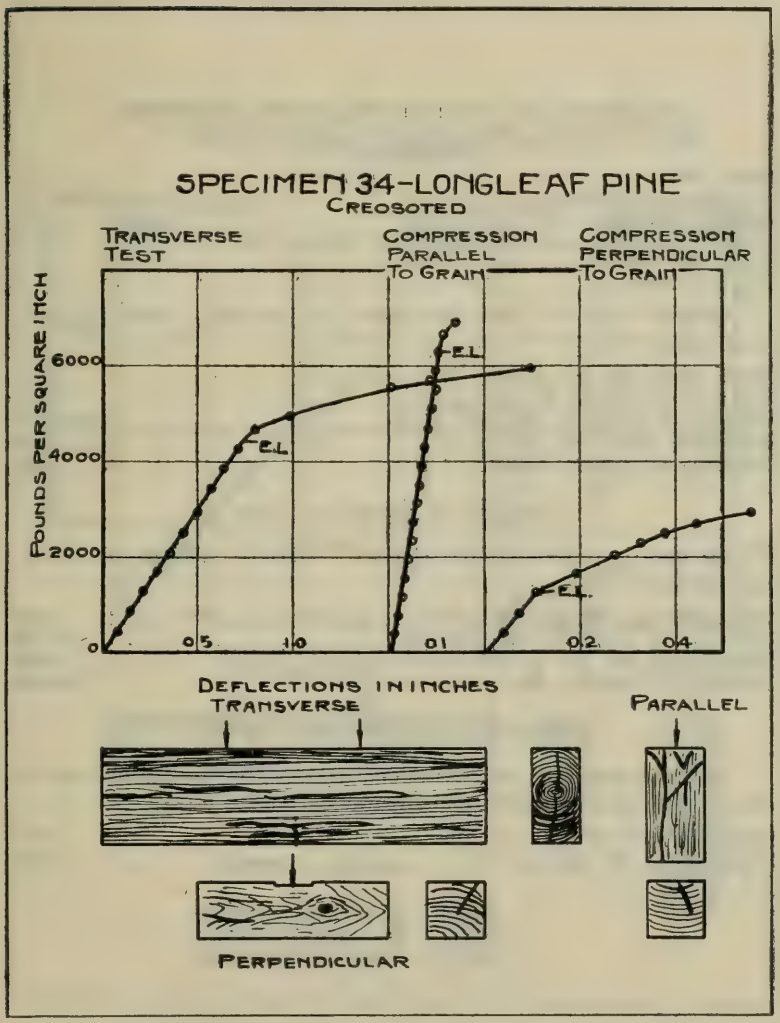
Specimen was straight-grained and failed by wedge shear.

Maximum load, lbs. per sq. in.	6,945
Deflection at maximum load, inches	0.14
Elastic limit, lbs. per sq. in.	6,300
Modulus of elasticity, lbs. per sq. in.	711,000

Compression Perpendicular to Grain.

Specimen had knot parallel to under plate. Failed by breaking fiber and crushing under plate.

Deflection under load of 2,990 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,250


SPECIMEN 34-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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DEFLECTIONS IN INCHES
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PARALLEL
PERPENDICULAR

SPECIMEN NO. 35—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.18
Weight, lbs. per cu. ft	39.5
Moisture, per cent	20.6
Rings, per cent	6
Sap, per cent	1.0

Specimen had two large spike knots on one side. Failed by horizontal shear.

Elastic limit, lbs. per sq. in	3,800
Modulus of rupture, lbs. per sq. in	5,100
Modulus of elasticity, lbs. per sq. in	1,344,000
Horizontal shear, lbs. per sq. in	399
Deflection at failure, inches	1.34

Compression Parallel to Grain.

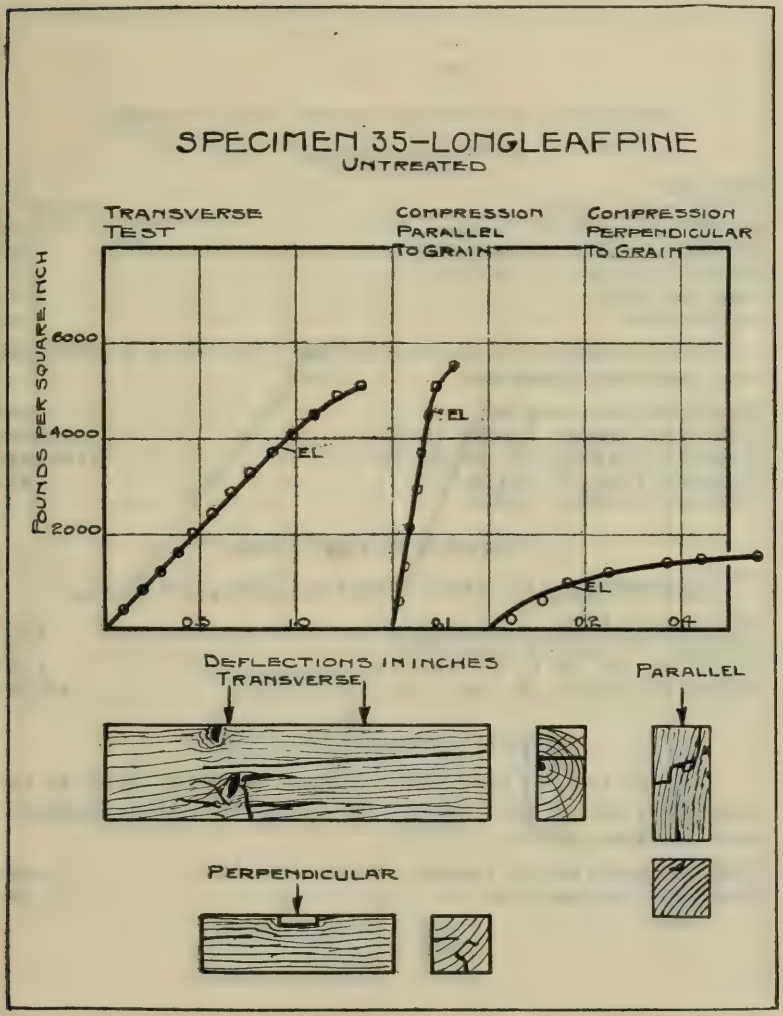
Specimen was fairly straight-grained. Failed by splitting and shearing near top.

Maximum load, lbs. per sq. in	5,473
Deflection at maximum load, inches	0.128
Elastic limit, lbs. per sq. in	4,600
Modulus of elasticity, lbs. per sq. in	693,000

Compression Perpendicular to Grain.

Specimen was badly cracked at one end, and slightly cracked on one side. Failed by splitting horizontally near one end.

Deflection under load of 1,574 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	900


SPECIMEN 35—LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 36—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.11
Weight, lbs. per cu. ft., treated	55.0
Weight, lbs. per cu. ft., untreated	42.9
Weight, lbs. per cu. ft., increase	12.1
Rings, per inch	6
Sap, per cent	1.0

This specimen had two knots on one side. The failure, by horizontal shear, was above a small knot.

Elastic limit, lbs. per sq. in	5,400
Modulus of rupture, lbs. per sq. in	6,040
Modulus of elasticity, lbs. per sq. in	1,639,000
Horizontal shear, lbs. per sq. in	467
Deflection at failure, inches	1.19

Compression Parallel to Grain.

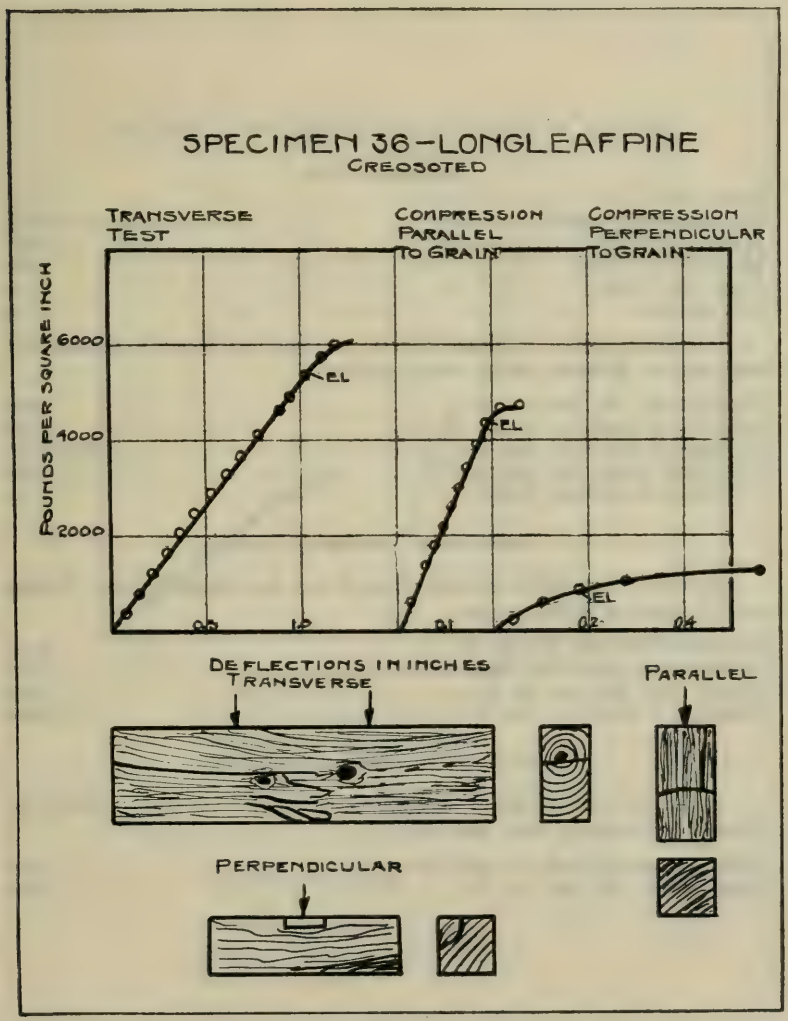
Specimen showed no defects. Failed by crushing and splitting.

Maximum load, lbs. per sq. in	4,595
Deflection at maximum load, inches	0.26
Elastic limit, lbs. per sq. in	4,300
Modulus of elasticity, lbs. per sq. in	275,000

Compression Perpendicular to Grain.

Specimen had one lower corner chipped. This was caused by the compression plate in the transverse test. Failed by splitting diagonally across one upper corner.

Deflection under load of 1,280 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	900


SPECIMEN 36—LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 37—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.12x7.24
Weight, lbs. per cu. ft	38.3
Moisture, per cent	18.0
Rings, per inch	12
Sap, per cent	35

Specimen showed a large knot on top and two large knots on side near center. Failure was by simple tension.

Elastic limit, lbs. per sq. in	2,900
Modulus of rupture, lbs. per sq. in	3,410
Modulus of elasticity, lbs. per sq. in	1,034,000
Horizontal shear, lbs. per sq. in	265
Deflection at failure, inches	1.4

Compression Parallel to Grain.

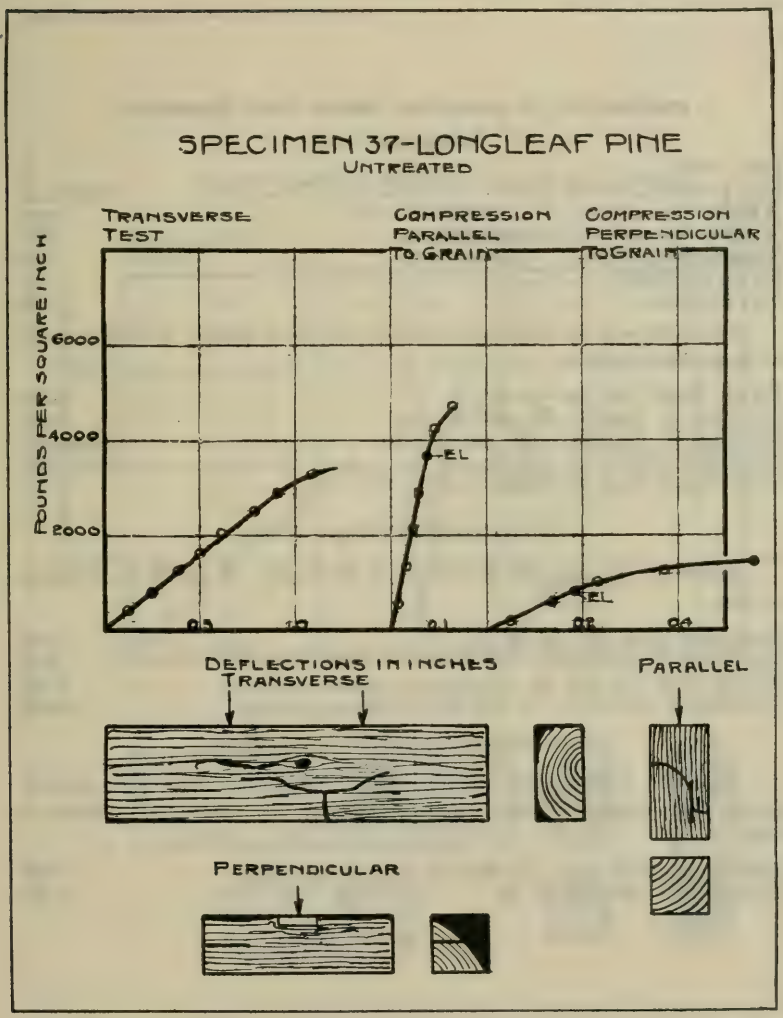
Specimen was fairly straight-grained and free from defects. Failure was by shearing across center.

Maximum load, lbs. per sq. in	4,720
Deflection at maximum load, inches	0.13
Elastic limit, lbs. per sq. in	3,700
Modulus of elasticity, lbs. per sq. in	633,000

Compression Perpendicular to Grain.

Specimen showed much sapwood at ends and one side. Failed by splitting horizontally near one end.

Deflection under load of 1,453 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	900


SPECIMEN 37-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 38—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.32
Weight, lbs. per cu. ft., treated	51.0
Weight, lbs. per cu. ft., untreated	36.2
Weight, lbs. per cu. ft., increase	14.8
Rings, per inch	12
Sap, per cent	35

Specimen was top timber and had several large knots. Failure was by cross-grained tension.

Elastic limit, lbs. per sq. in	4,100
Modulus of rupture, lbs. per sq. in	4,035
Modulus of elasticity, lbs. per sq. in	1,090,000
Horizontal shear, lbs. per sq. in	315
Deflection at time of failure, inches	1.2

Compression Parallel to Grain.

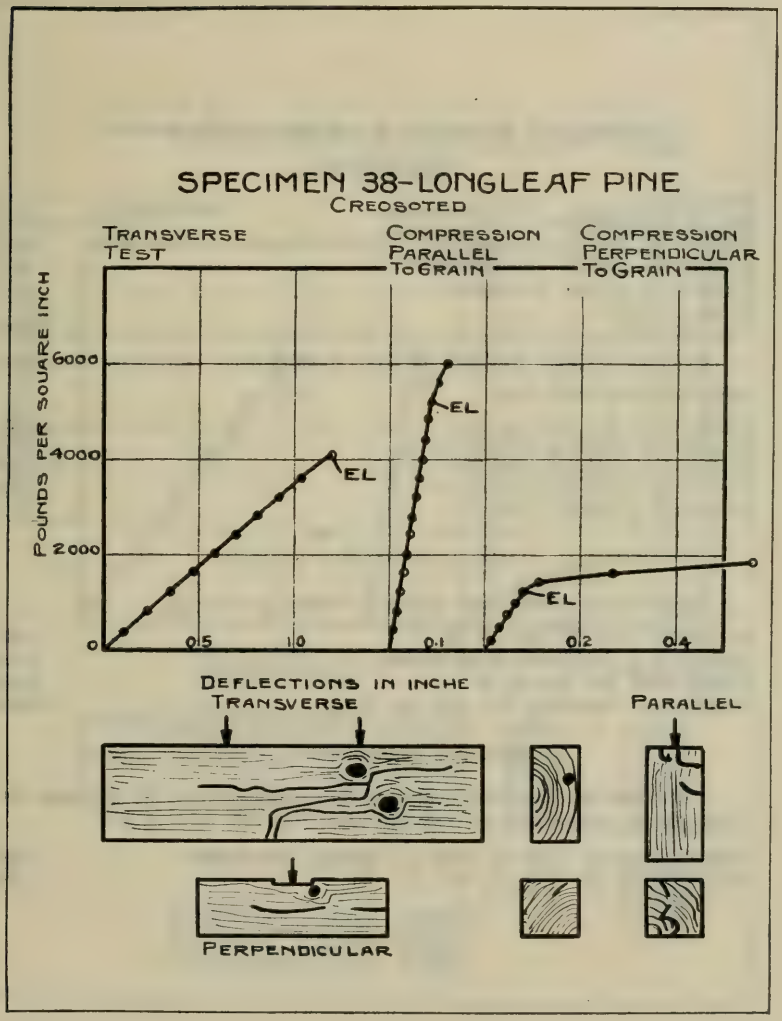
Specimen was straight-grained with no knots. It failed by crushing on top.

Maximum load, lbs. per sq. in	6,012
Deflection at maximum load, inches	0.12
Elastic limit, lbs. per sq. in	5,200
Modulus of elasticity, lbs. per sq. in	719,000

Compression Perpendicular to Grain.

Specimen had a knot directly under where the plate was applied. Grain was straight. Failure was by crushing under plate and splitting to side.

Deflection under load of 1,863 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,050


SPECIMEN 38-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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PERPENDICULAR

SPECIMEN NO. 39—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.35x7.25
Weight, lbs. per cu. ft., treated	56.8
Weight, lbs. per cu. ft., untreated	44.1
Weight, lbs. per cu. ft., increase	12.7
Rings, per inch	15
Sap, per cent	None

Specimen straight-grained and free from defects. Failed in horizontal shear following year rings.

Elastic limit, lbs. per sq. in	4,900
Modulus of rupture, lbs. per sq. in	5,635
Modulus of elasticity, lbs. per sq. in	1,632,000
Horizontal shear, lbs. per sq. in	442
Deflection at failure, inches	1.11

Compression Parallel to Grain.

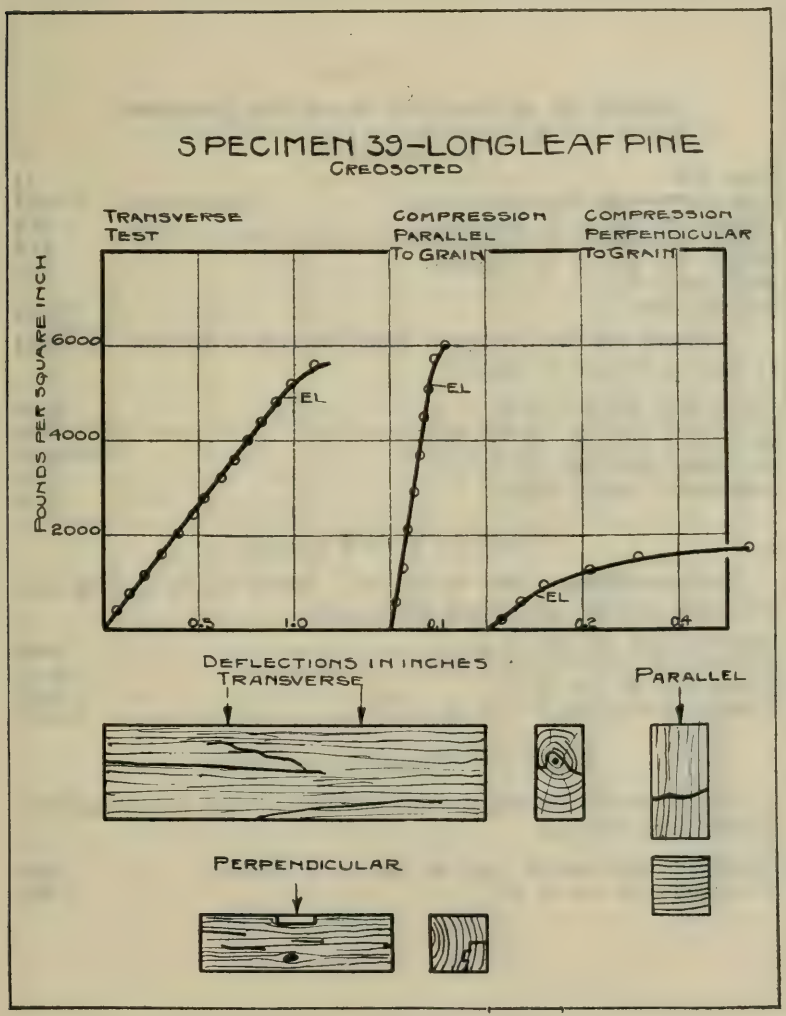
Specimen was free from defects. Failed by crushing.

Maximum load, lbs. per sq. in	6,052
Deflection at maximum load, inches	0.119
Elastic limit, lbs. per sq. in	5,200
Modulus of elasticity, lbs. per sq. in	779,000

Compression Perpendicular to Grain.

Piece had several cracks on one side. Failure was by splitting vertically from bottom and horizontally from one side, at one end.

Deflection under load of 1,686 lbs. per sq. in., inches	0.553
Elastic limit, lbs. per sq. in	800


SPECIMEN 39—LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 40—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.1x7.1
Weight, lbs. per cu. ft., treated	57.0
Weight, lbs. per cu. ft., untreated	41.1
Weight, lbs. per cu. ft., increase	15.9
Rings, per inch	15
Sap, per cent	None

Specimen had four free knots about one inch in diameter. It failed by shearing through two knots.

Elastic limit, lbs. per sq. in	4,400
Modulus of rupture, lbs. per sq. in	4,660
Modulus of elasticity, lbs. per sq. in	1,623,000
Horizontal shear, lbs. per sq. in	393
Deflection at failure, inches	0.94

Compression Parallel to Grain.

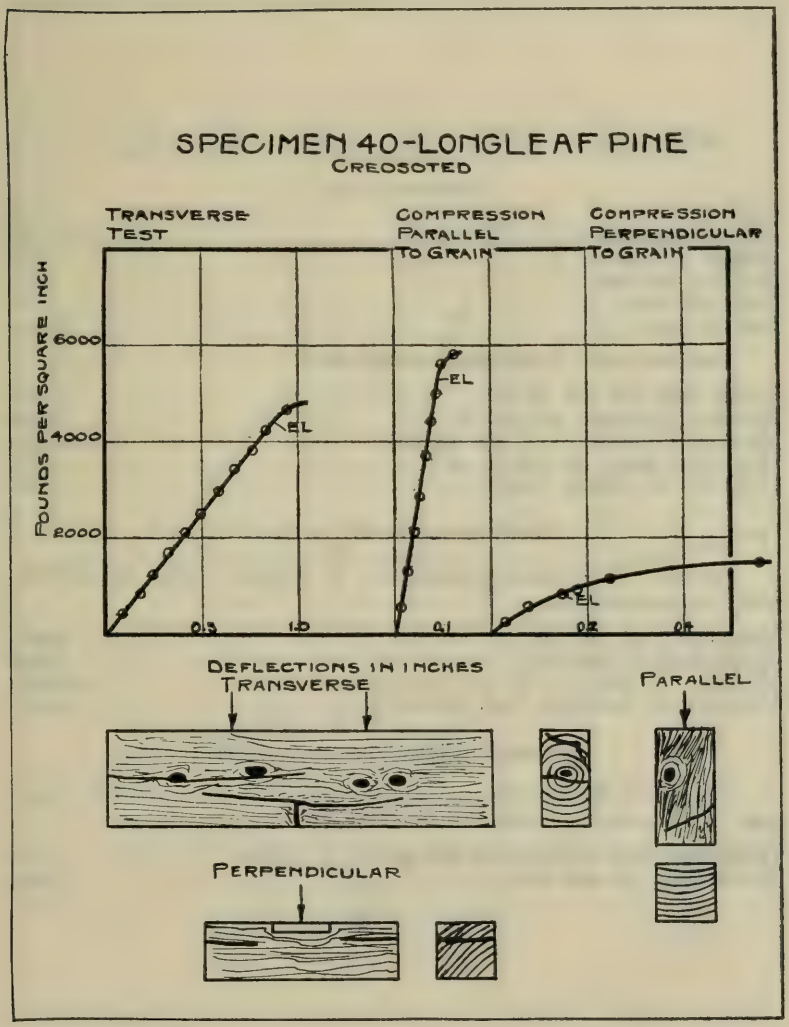
Specimen showed a knot on one side. Failure was by shearing near the bottom and was not affected by the knot.

Maximum load, lbs. per sq. in	6,002
Deflection at maximum load, inches	0.121
Elastic limit, lbs. per sq. in	5,300
Modulus of elasticity, lbs. per sq. in	704,000

Compression Perpendicular to Grain.

Piece showed a straight grain on the sides. Failed by splitting horizontally from each end.

Deflection under load of 1,485 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	800


SPECIMEN 40-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 41—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.6x7.37
Weight, lbs. per cu. ft	41.8
Moisture, per cent	35.6
Rings, per inch	6
Sap, per cent	None

Specimen clear. Failed by horizontal shear.

Elastic limit, lbs. per sq. in	4,500
Modulus of rupture, lbs. per sq. in	4,840
Modulus of elasticity, lbs. per sq. in	1,652,000
Horizontal shear, lbs. per sq. in	386
Deflection at failure, inches	0.92

Compression Parallel to Grain.

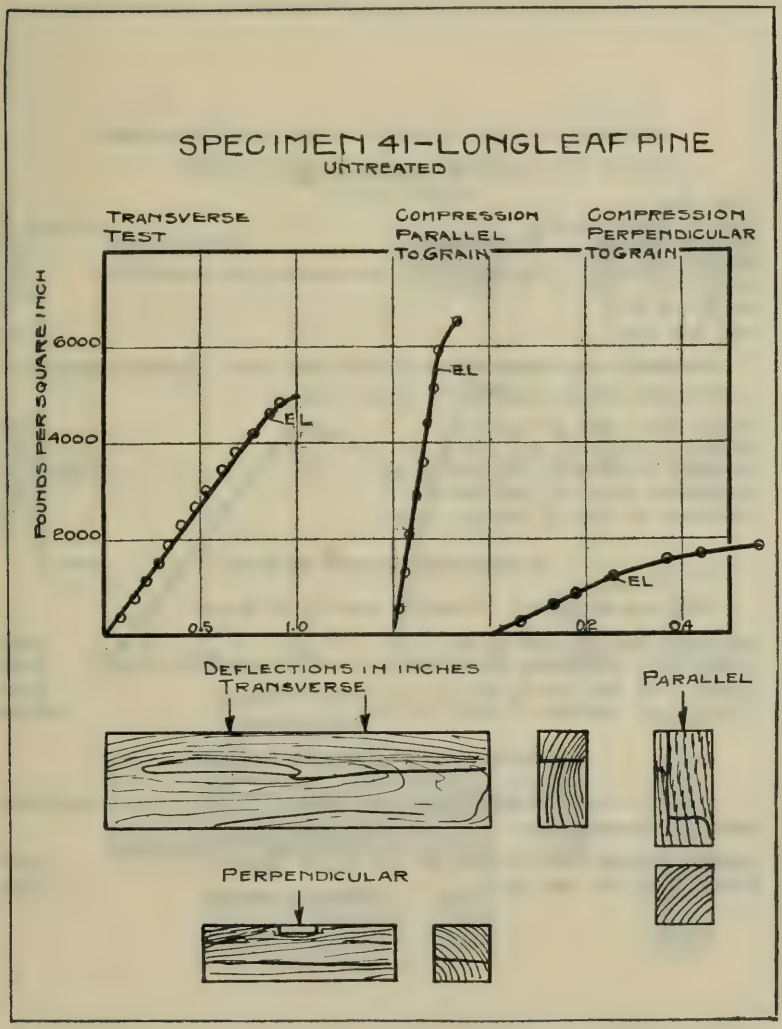
Specimen was straight-grained with no defects. Failed by splitting and crushing near bottom.

Maximum load, lbs. per sq. in	6,580
Elastic limit, lbs. per sq. in	5,500
Modulus of elasticity, lbs. per sq. in	734,000
Deflection at maximum load, inches	0.136

Compression Perpendicular to Grain.

One end of the specimen was badly cracked and crack showed on one side. Failure was by horizontal shear following crack on the side.

Deflection under load of 1,799 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,200


SPECIMEN 41—LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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PERPENDICULAR

SPECIMEN NO. 42—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.38
Weight, lbs. per cu. ft., treated	48.8
Weight, lbs. per cu. ft., untreated	38.7
Weight, lbs. per cu. ft., increase	10.1
Rings, per inch	6
Sap, per cent	0.5

Specimen was straight-grained with few knots. Failure was caused by horizontal shear and later by simple tension.

Elastic limit, lbs. per sq. in	4,700
Modulus of rupture, lbs. per sq. in	4,800
Modulus of elasticity, lbs. per sq. in	1,576,000
Horizontal shear, lbs. per sq. in	375
Deflection at time of failure, inches	0.96

Compression Parallel to Grain.

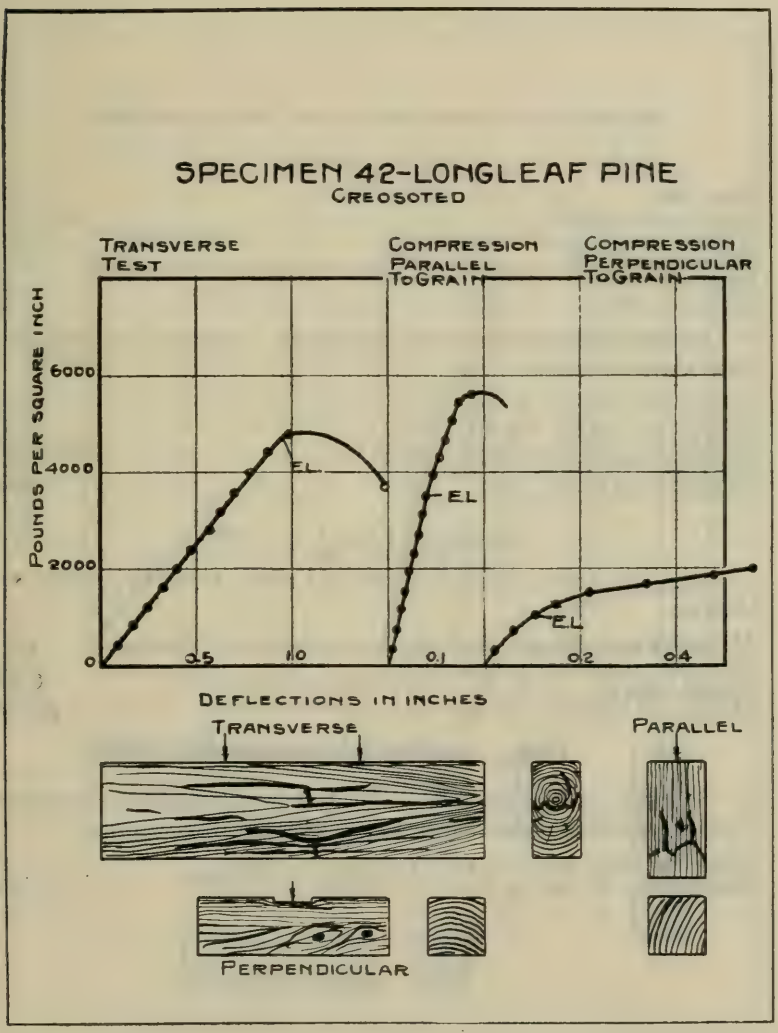
Stick had no defects. Failed by crushing at bottom.

Maximum load, lbs. per sq. in	5,604
Deflection at maximum load, inches	0.178
Elastic limit, lbs. per sq. in	3,500
Modulus of elasticity, lbs. per sq. in	526,000

Compression Perpendicular to Grain.

Specimen had bad shake with some knots. Failed by crushing under plate and breaking fiber.

Deflection under load of 2,013 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,000


SPECIMEN 42-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 43—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.2x7.35
Weight, lbs. per cu. ft.	43.0
Moisture, per cent	18.3
Rings, per inch	17
Sap, per cent	12

Specimen had wide heart shake and checks. Failure was by horizontal shear along the shake.

Elastic limit, lbs. per sq. in.	2,600
Modulus of rupture, lbs. per sq. in.	3,640
Modulus of elasticity, lbs. per sq. in.	1,433,000
Horizontal shear, lbs. per sq. in.	283
Deflection at failure, inches	0.88

Compression Parallel to Grain.

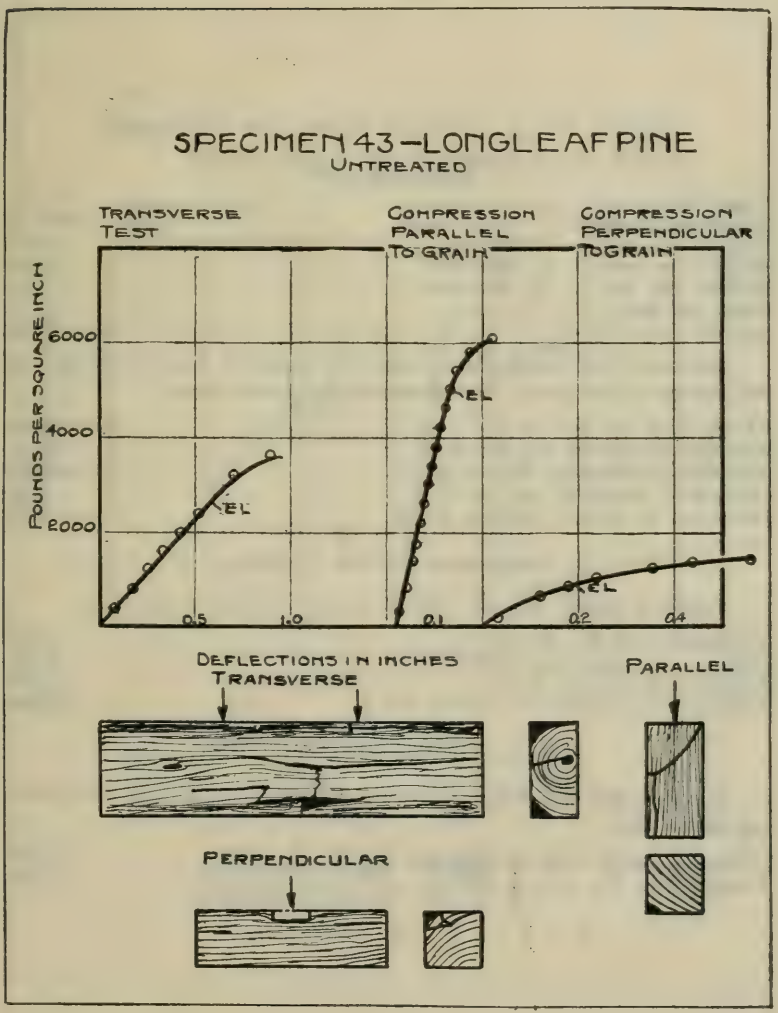
Specimen showed sapwood on ends and sides. Failed by splitting and shearing.

Maximum load, lbs. per sq. in.	6,063
Deflection at maximum load, inches	0.22
Elastic limit, lbs. per sq. in.	5,000
Modulus of elasticity, lbs. per sq. in.	432,000

Compression Perpendicular to Grain.

Specimen was straight-grained and showed some sapwood at the ends. Failed by splitting horizontally at both ends.

Deflection under load of 1,438 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	900


SPECIMEN 43—LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 44—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.10x7.15
Weight, lbs. per cu. ft., treated	54.6
Weight, lbs. per cu. ft., untreated	49.2
Weight, lbs. per cu. ft., increase	5.4
Rings, per inch	17
Sap, per cent	12

Specimen was sawed transversely, the center of heart being in one end but out of the other. Failure was by horizontal shear.

Elastic limit, lbs. per sq. in	4,700
Modulus of rupture, lbs. per sq. in	6,737
Modulus of elasticity, lbs. per sq. in	1,542,000
Horizontal shear, lbs. per sq. in	520
Deflection at time of failure, inches	0.96

Compression Parallel to Grain.

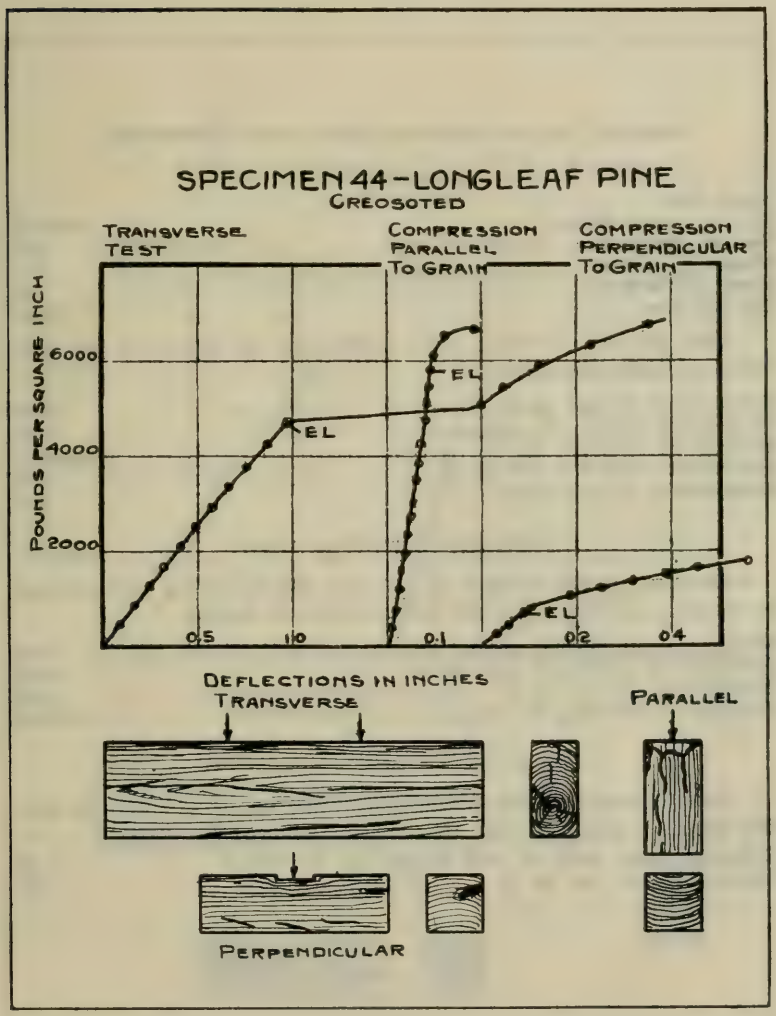
Specimen had no defects. Failed at top by double wedge shear.

Maximum load, lbs. per sq. in	6,656
Deflection at maximum load, inches	0.192
Elastic limit, lbs. per sq. in	5,800
Modulus of elasticity, lbs. per sq. in	776,000

Compression Perpendicular to Grain.

Specimen had bad shake. Failed by splitting through shake and crushing under plate.

Deflection under load of 2,750 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	700


SPECIMEN 44 - LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 45—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x6.75
Weight, lbs. per cu. ft.	39.0
Moisture, per cent	17.2
Rings, per inch	11
Sap, per cent	None

This specimen showed a pitch pocket near the center on one side. Failed by horizontal shear.

Elastic limit, lbs. per sq. in.	4,800
Modulus of rupture, lbs. per sq. in.	6,060
Modulus of elasticity, lbs. per sq. in.	1,808,000
Horizontal shear, lbs. per sq. in.	466
Deflection at failure, inches	1.16

Compression Parallel to Grain.

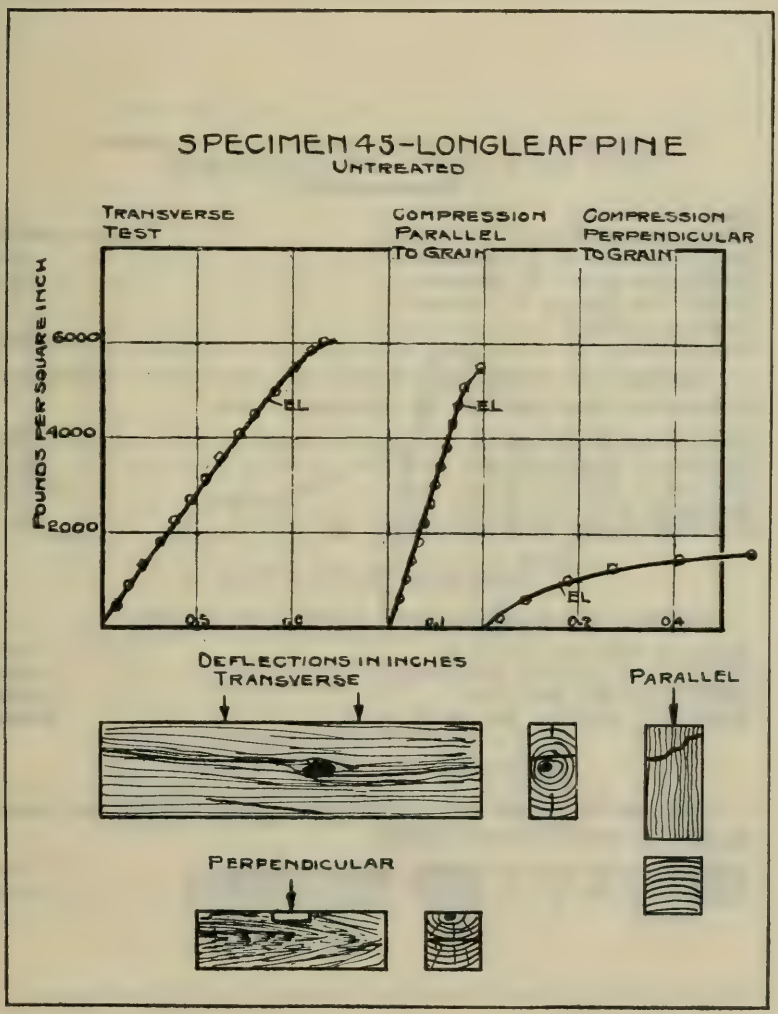
Specimen showed a crack on one side before loading. Failure was by crushing near top. The split did not affect the failure.

Maximum load, lbs. per sq. in.	5,492
Deflection at maximum load, inches	0.192
Elastic limit, lbs. per sq. in.	4,700
Modulus of elasticity, lbs. per sq. in.	380,000

Compression Perpendicular to Grain.

Piece showed sapwood at ends and a crack on one side near the end. The failure, a horizontal split near one end, followed this crack.

Deflection under load of 1,618 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	900


SPECIMEN 45-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 46—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.24
Weight, lbs. per cu. ft., treated	46.4
Weight, lbs. per cu. ft., untreated	38.4
Weight, lbs. per cu. ft., increase	8.0
Rings, per inch	11
Sap, per cent	None

Specimen was straight-grained with some heart shake. Failure was by horizontal shear and later by splintering tension.

Elastic limit, lbs. per sq. in.	2,800
Modulus of rupture, lbs. per sq. in.	4,014
Modulus of elasticity, lbs. per sq. in.	1,416,000
Horizontal shear, lbs. per sq. in.	314
Deflection at time of failure, inches	0.625

Compression Parallel to Grain.

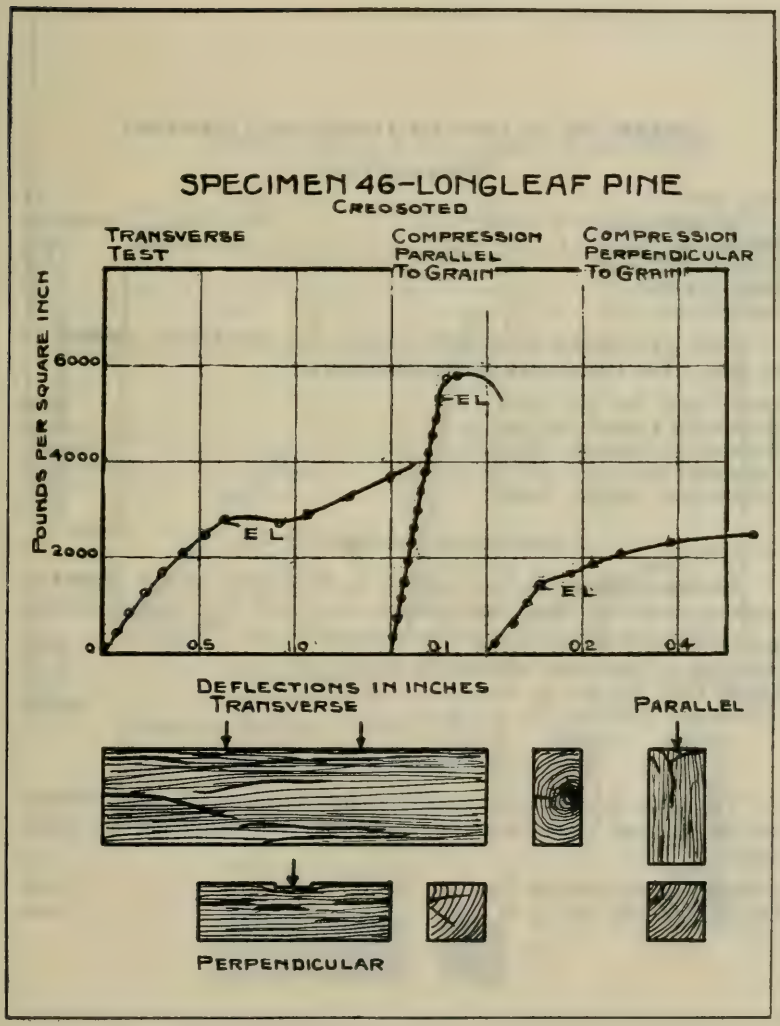
Specimen was straight-grained. Failed by wedge shear.

Maximum load, lbs. per sq. in.	5,760
Deflection at maximum load, inches	0.139
Elastic limit, lbs. per sq. in.	5,300
Modulus of elasticity, lbs. per sq. in.	653,000

Compression Perpendicular to Grain.

Specimen had shake and was straight-grained. Failure was caused by crushing under plate and splitting.

Deflection under load of 2,450 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,350


SPECIMEN 46-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
0
E L
E L
E L
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 47—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.2x7.19
Weight, lbs. per cu. ft	37.5
Moisture, per cent	6.2
Rings, per inch	10
Sap, per cent	5

Piece was warped quite badly. There was considerable sapwood at the ends. The failure was by horizontal shear.

Elastic limit, lbs. per sq. in	3,500
Modulus of rupture, lbs. per sq. in	3,900
Modulus of elasticity, lbs. per sq. in	1,454,000
Horizontal shear, lbs. per sq. in	341
Deflection at failure, inches	0.93

Compression Parallel to Grain.

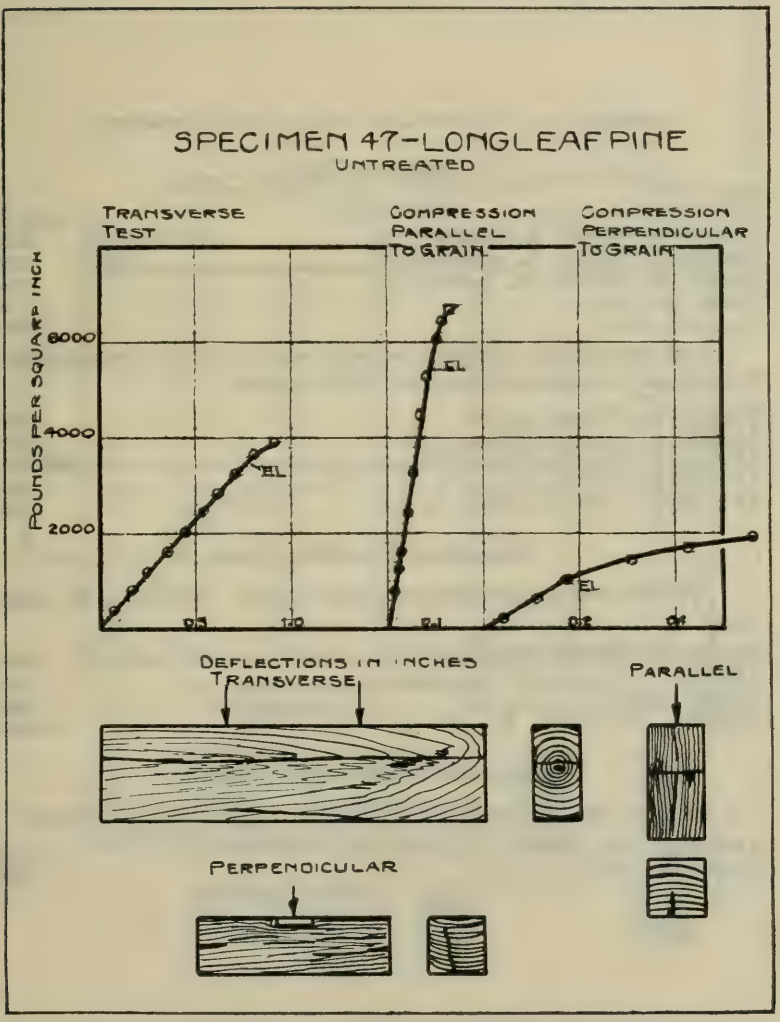
Specimen had a spike knot one-half by three inches on top. Failed by cracking across the center and splitting downward from crushed section.

Maximum load, lbs. per sq. in	6,450
Deflection at maximum load, inches	0.128
Elastic limit, lbs. per sq. in	5,400
Modulus of elasticity, lbs. per sq. in	720,000

Compression Perpendicular to Grain.

This piece showed sapwood at ends and cracks on one side. Failure was by splitting vertically at one end. The side crack did not affect failure.

Deflection under load of 1,906 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,100


SPECIMEN 47-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
8000
4000
2000
EL
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 48—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.37x7.13
Weight, lbs. per cu. ft., treated	46.8
Weight, lbs. per cu. ft., untreated	41.6
Weight, lbs. per cu. ft., increase	5.2
Rings, per inch	10
Sap, per cent	None

Stick was slightly cross-grained with weather checks through heart. Failure was by horizontal shear and brittle tension.

Elastic limit, lbs. per sq. in	3,250
Modulus of rupture, lbs. per sq. in	5,312
Modulus of elasticity, lbs. per sq. in	1,470,000
Horizontal shear, lbs. per sq. in	412
Deflection at time of failure, inches	2.9

Compression Parallel to Grain.

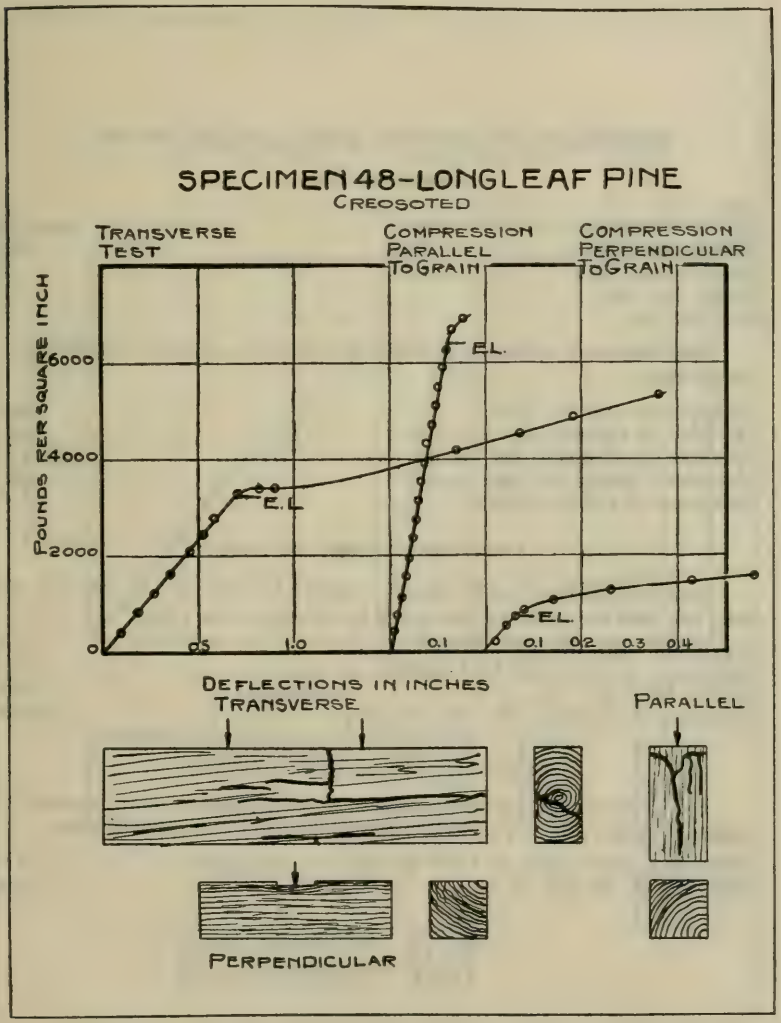
Specimen was straight-grained with no defects. Failure was by wedge shear.

Maximum load, lbs. per sq. in	6,905
Deflection at maximum load, inches	0.15
Elastic limit, lbs. per sq. in	6,400
Modulus of elasticity, lbs. per sq. in	646,400

Compression Perpendicular to Grain.

Specimen had one knot at the end. Failed by crushing under plate.

Deflection under load of 1,571 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	800


SPECIMEN 48-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
0
E.L.
E.L.
E.L.
0.5
1.0
0.1
0.1
0.2
0.3
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 49—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x7.15
Weight, lbs. per cu. ft	38.4
Moisture, per cent	18
Rings, per inch	7
Sap, per cent	6

Specimen had a few small knots on one side. Failure was by horizontal shear.

Elastic limit, lbs. per sq. in	4,200
Modulus of rupture, lbs. per sq. in	5,200
Modulus of elasticity, lbs. per sq. in	1,511,000
Horizontal shear, lbs. per sq. in	400
Deflection at failure, inches	1.28

Compression Parallel to Grain.

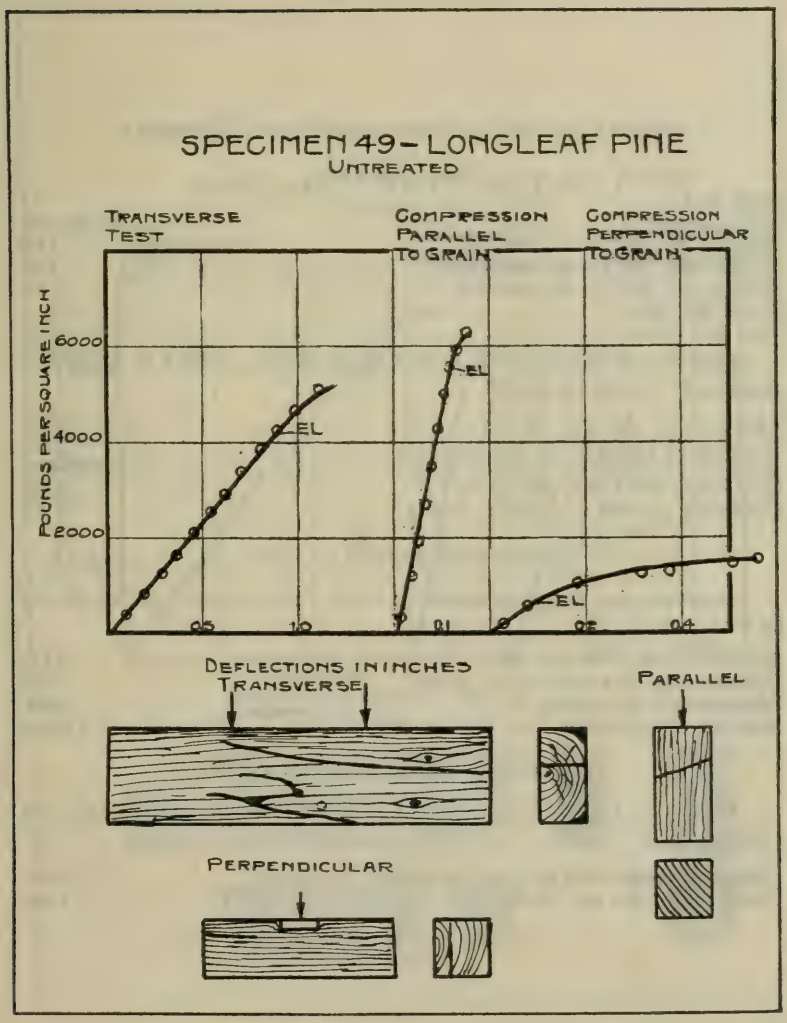
Specimen had two spike knots, one-half by one inch in size, on one side, one near each end. Failure was by shearing near center.

Maximum load, lbs. per sq. in	6,310
Deflection at maximum load, inches	0.563
Elastic limit, lbs. per sq. in	5,600
Modulus of elasticity, lbs. per sq. in	558,000

Compression Perpendicular to Grain.

Piece was straight-grained, free from knots, with a small amount of sapwood at the ends. Failed by splitting horizontally near the ends.

Deflection under load of 1,506 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	700


SPECIMEN 49 – LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
.05
.10
.01
.02
.04
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 50—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center	16.06x7.09
Weight, lbs. per cu. ft., treated	55.8
Weight, lbs. per cu. ft., untreated	42.3
Weight, lbs. per cu. ft., increase	13.5
Rings, per inch	7
Sap, per cent	6

Specimen straight-grained, with weather checks. Failed by horizontal shear and by intering tension.

Elastic limit, lbs. per sq. in	5,900
Modulus of rupture, lbs. per sq. in	7,114
Modulus of elasticity, lbs. per sq. in	1,586,000
Horizontal shear, lbs. per sq. in	550
Deflection at time of failure, inches	1.2

Compression Parallel to Grain.

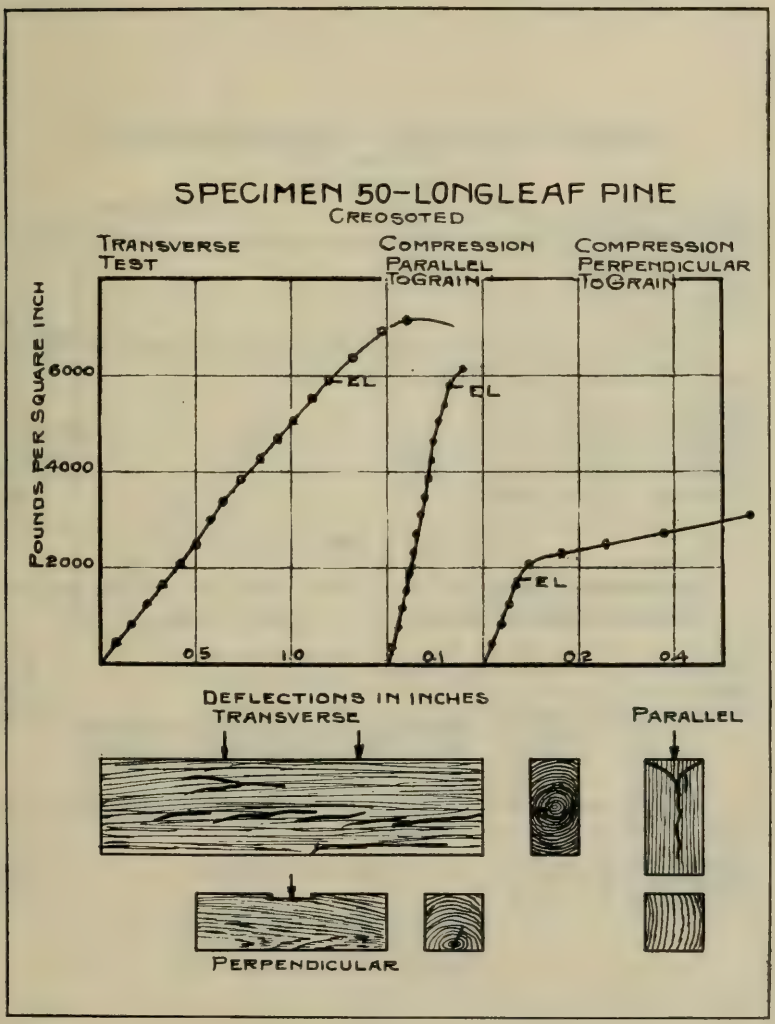
Specimen was straight-grained and free from defects. Failed on top by wedge shear.

Maximum load, lbs. per sq. in	6,150
Deflection at maximum load, inches	0.16
Elastic limit, lbs. per sq. in	5,800
Modulus of elasticity, lbs. per sq. in	539,000

Compression Perpendicular to Grain.

Piece was free from defects. Failed by crushing under plate and crushing fiber.

Deflection under load of 3,125 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,400


SPECIMEN 50-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 51—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.42
Weight, lbs. per cu. ft	40.3
Moisture, per cent	8.5
Rings, per inch	9
Sap, per cent	None

Piece had no defects excepting a few pin knots on one side. Failure was by horizontal shear following year rings.

Elastic limit, lbs. per sq. in	3,600
Modulus of rupture, lbs. per sq. in	4,000
Modulus of elasticity, lbs. per sq. in	1,435,000
Horizontal shear, lbs. per sq. in	348
Deflection at failure, inches	0.91

Compression Parallel to Grain.

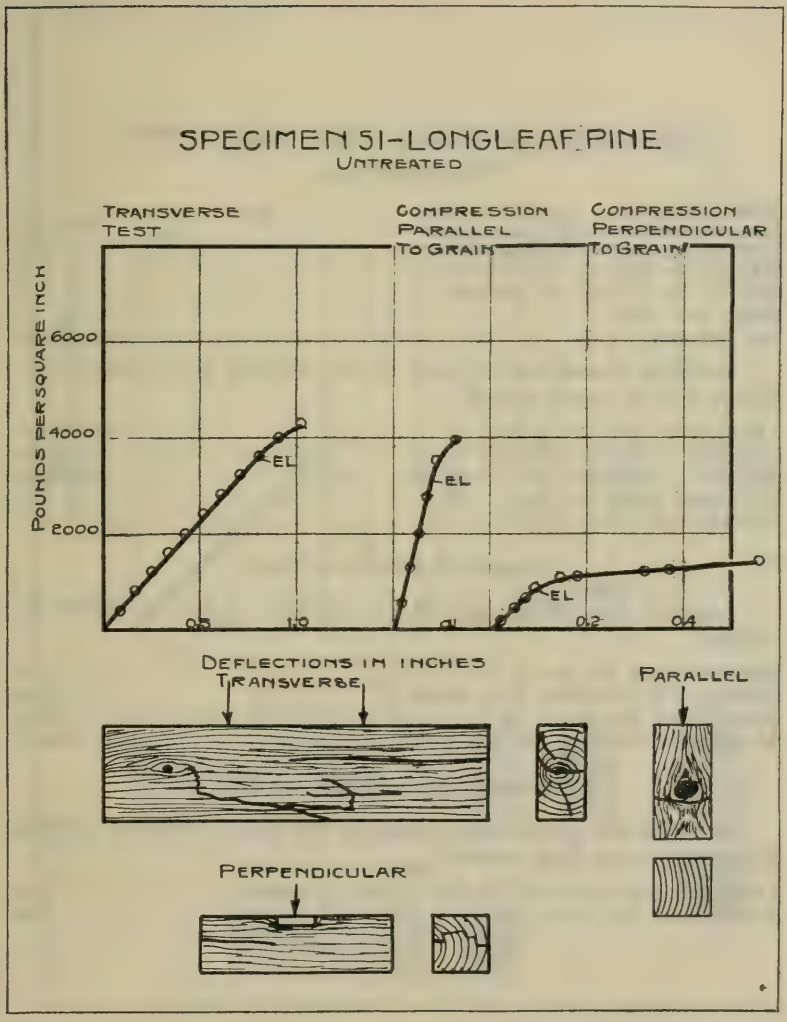
Specimen had a large knot in one side. Failed by crushing near center below and around the knot.

Maximum load, lbs. per sq. in	3,951
Deflection at maximum load, inches	0.126
Elastic limit, lbs. per sq. in	3,100
Modulus of elasticity, lbs. per sq. in	464,000

Compression Perpendicular to Grain.

The specimen showed two spike knots on top and some sapwood at the ends. Failed by splitting horizontally near one end.

Deflection under load of 1,419 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	800


SPECIMEN 51-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 52—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.6x7.35
Weight, lbs. per cu. ft., treated	49.9
Weight, lbs. per cu. ft., untreated	38.3
Weight, lbs. per cu. ft., increase	11.6
Rings, per inch	9
Sap, per cent	None

Specimen showed six pin knots on one side and dry rot on bottom. Failure was by simple tension.

Elastic limit, lbs. per sq. in	3,400
Modulus of rupture, lbs. per sq. in	4,160
Modulus of elasticity, lbs. per sq. in	1,178,000
Horizontal shear, lbs. per sq. in	332
Deflection at failure, inches	1.16

Compression Parallel to Grain.

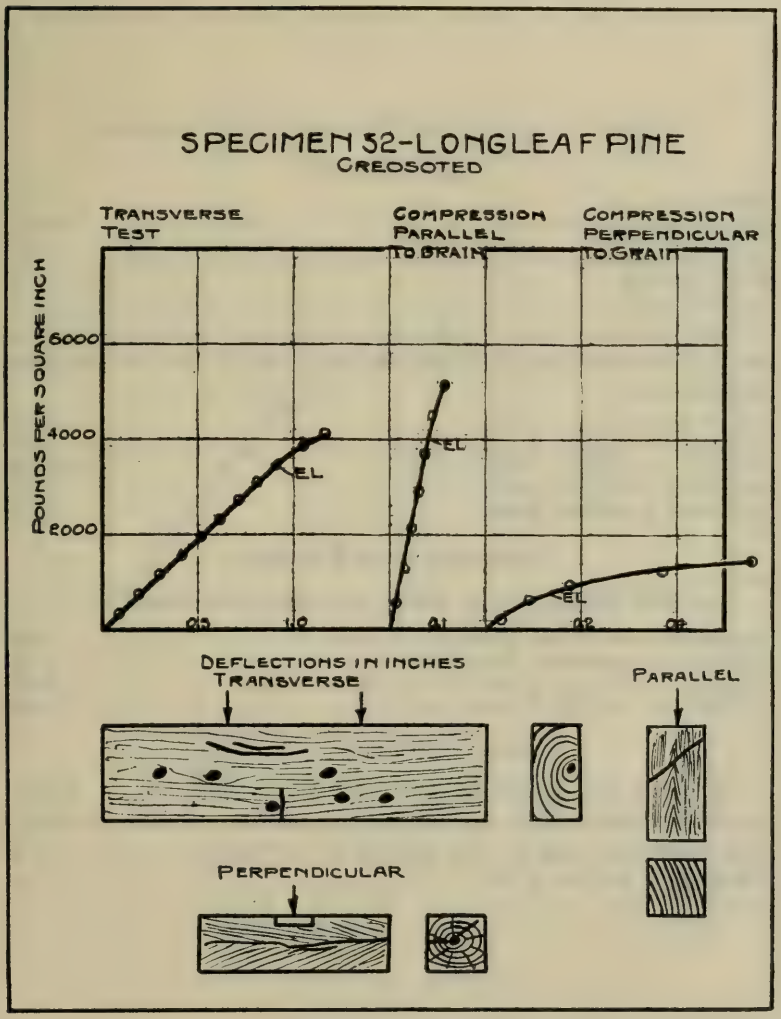
Specimen was straight-grained and showed no defects. Failed by shearing.

Maximum load, lbs. per sq. in	5,177
Deflection at maximum load, inches	0.119
Elastic limit, lbs. per sq. in	4,000
Modulus of elasticity, lbs. per sq. in	574,000

Compression Perpendicular to Grain.

Specimen had several light cracks on the sides. Failed by splitting horizontally along these cracks.

Deflection under load of 1,464 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	800


SPECIMEN 52-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
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1.0
.1
.2
.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 53—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	15.9x7.1
Weight, lbs. per cu. ft.	36.8
Moisture, per cent	13.7
Rings, per inch	20
Sap, per cent	1.0

The specimen showed a heart shake and several small knots. Failure was by horizontal shear following the knots on the side and the shake through center.

Elastic limit, lbs. per sq. in	3,800
Modulus of rupture, lbs. per sq. in	4,880
Modulus of elasticity, lbs. per sq. in	1,904,000
Horizontal shear, lbs. per sq. in	373
Deflection at failure, inches	0.92

Compression Parallel to Grain.

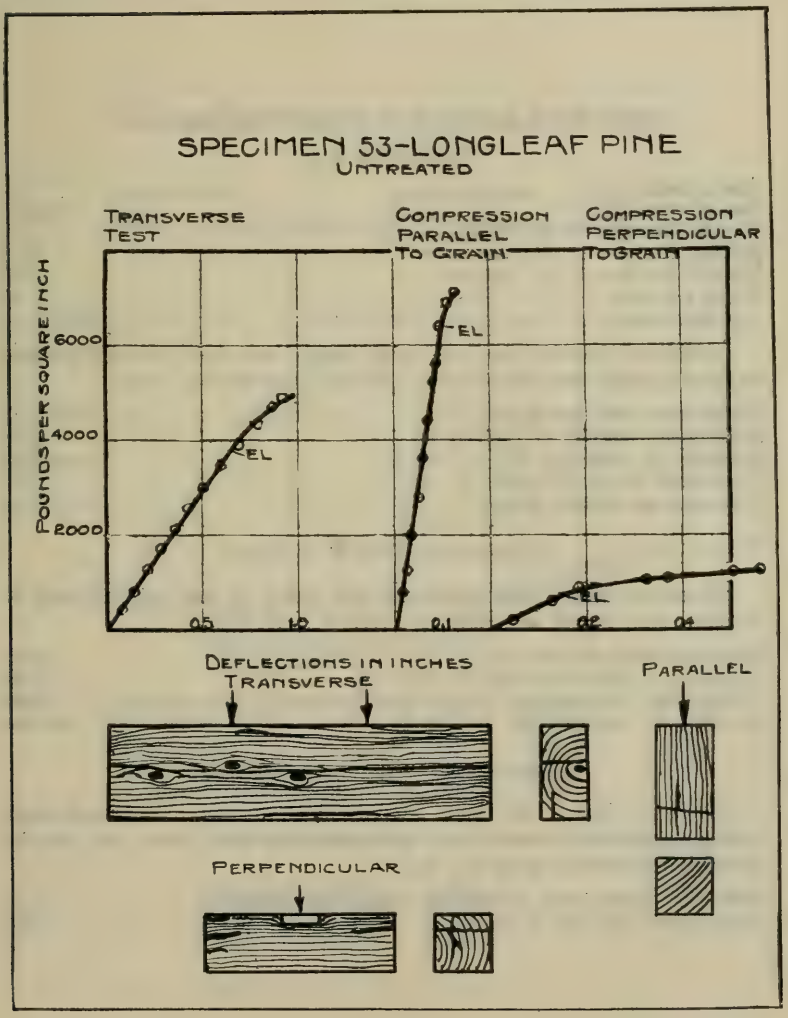
Specimen had no defects. Failed by crushing near bottom.

Maximum load, lbs. per sq. in	7,040
Deflection at maximum load, inches	0.126
Elastic limit, lbs. per sq. in	6,200
Modulus of elasticity, lbs. per sq. in	786,000

Compression Perpendicular to Grain.

Specimen was straight-grained, and had two cracks on top. Failure was by splitting vertically near one end, the fracture following the cracks.

Deflection under load of 1,395 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	700


SPECIMEN 53-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
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1.0
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 54—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x7.1
Weight, lbs. per cu. ft., treated	48.5
Weight, lbs. per cu. ft., untreated	37.8
Weight, lbs. per cu. ft., increase	10.7
Rings, per inch	20
Sap, per cent	1.0

Specimen showed wane on three edges, was fairly straight-grained and had a large knot on one side. Failed in splintering tension.

Elastic limit, lbs. per sq. in.	4,200
Modulus of rupture, lbs. per sq. in.	4,900
Modulus of elasticity, lbs. per sq. in.	1,600,000
Horizontal shear, lbs. per sq. in.	410
Deflection at failure, inches	1.04

Compression Parallel to Grain.

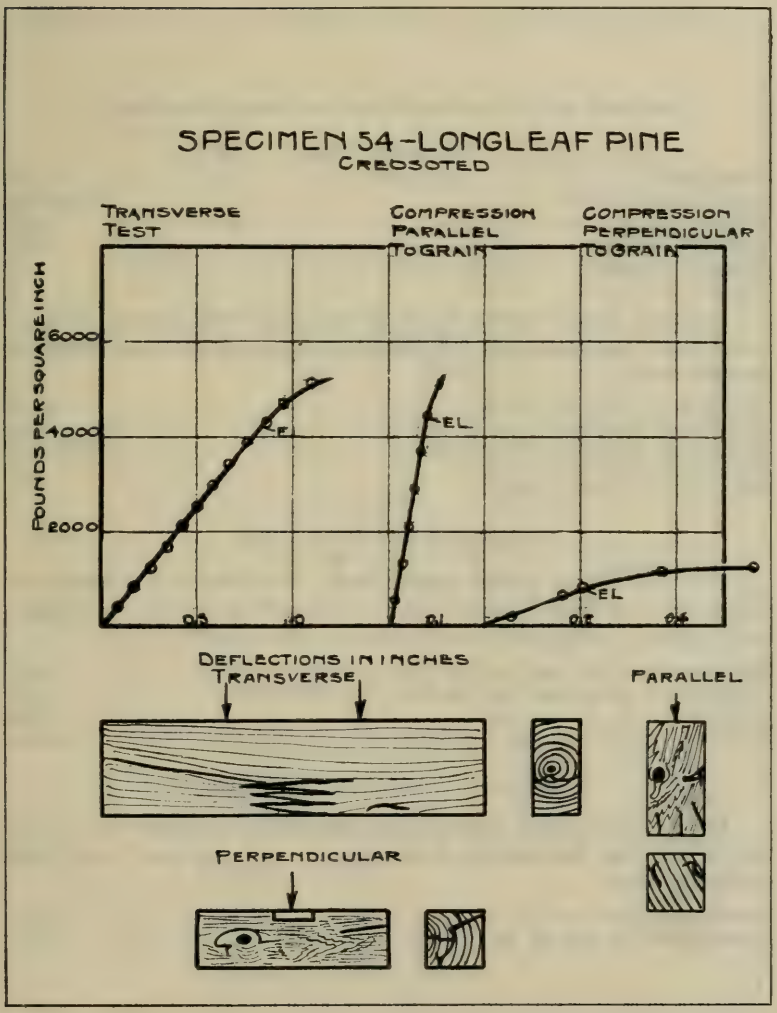
Specimen had a large knot near the center of one side. Failed by crushing near center and splitting upward from bottom.

Maximum load, lbs. per sq. in.	5,172
Deflection at maximum load, inches	0.102
Elastic limit, lbs. per sq. in.	4,400
Modulus of elasticity, lbs. per sq. in.	664,000

Compression Perpendicular to Grain.

Specimen had a pin knot on top side and was straight-grained. Failed by splitting around knot, split following year rings, and also by splitting horizontally from one end.

Deflection under load of 1,288 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	800


SPECIMEN 54 - LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 55—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.35x7.22
Weight, lbs. per cu. ft	47.7
Moisture, per cent	18.6
Rings, per inch	11
Sap, per cent	6

Specimen showed several knots on the sides. The failure, by horizontal shear, was apparently not effected by the knots, the shear following the year rings.

Elastic limit, lbs. per sq. in	4,400
Modulus of rupture, lbs. per sq. in	5,500
Modulus of elasticity, lbs. per sq. in	1,688,000
Horizontal shear, lbs. per sq. in	432
Deflection at failure, inches	1.13

Compression Parallel to Grain.

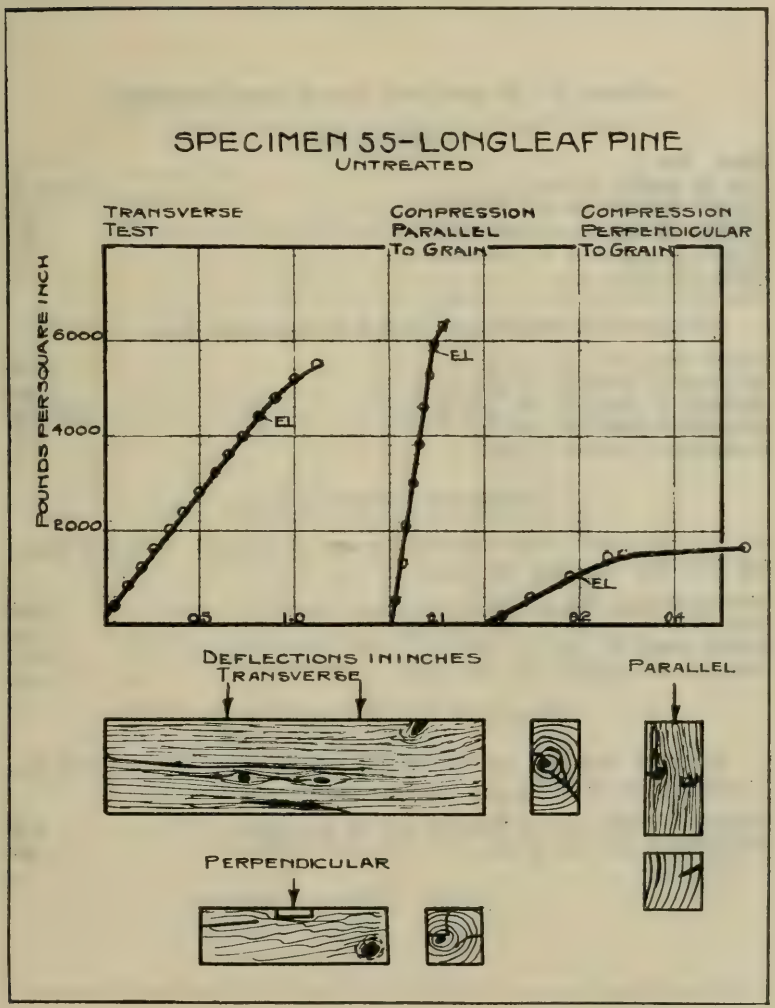
Specimen showed a large central knot. The failure by splitting, extended from the knot downward on one side and upward on the opposite side.

Maximum load, lbs. per sq. in	6,301
Deflection at maximum load, inches	0.116
Elastic limit, lbs. per sq. in	5,800
Modulus of elasticity, lbs. per sq. in	772,000

Compression Perpendicular to Grain.

Piece showed a large solid knot near the end on one side. The failure was by splitting horizontally at the opposite end and was in no way effected by knot.

Deflection under load of 1,659 lbs. per sq. in., inches	0.553
Elastic limit, lbs. per sq. in	1,100


SPECIMEN 55-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
.05
1.0
.01
.02
.04
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 56—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.6x7.25
Weight, lbs. per cu. ft., treated	59.8
Weight, lbs. per cu. ft., untreated	50.7
Weight, lbs. per cu. ft., increase	9.1
Rings, per inch	11
Sap, per cent	6

This specimen had shakes. Failed in horizontal shear.

Elastic limit, lbs. per sq. in	4,000
Modulus of rupture, lbs. per sq. in	4,460
Modulus of elasticity, lbs. per sq. in	1,670,000
Horizontal shear, lbs. per sq. in	387
Deflection at failure, inches	0.87

Compression Parallel to Grain.

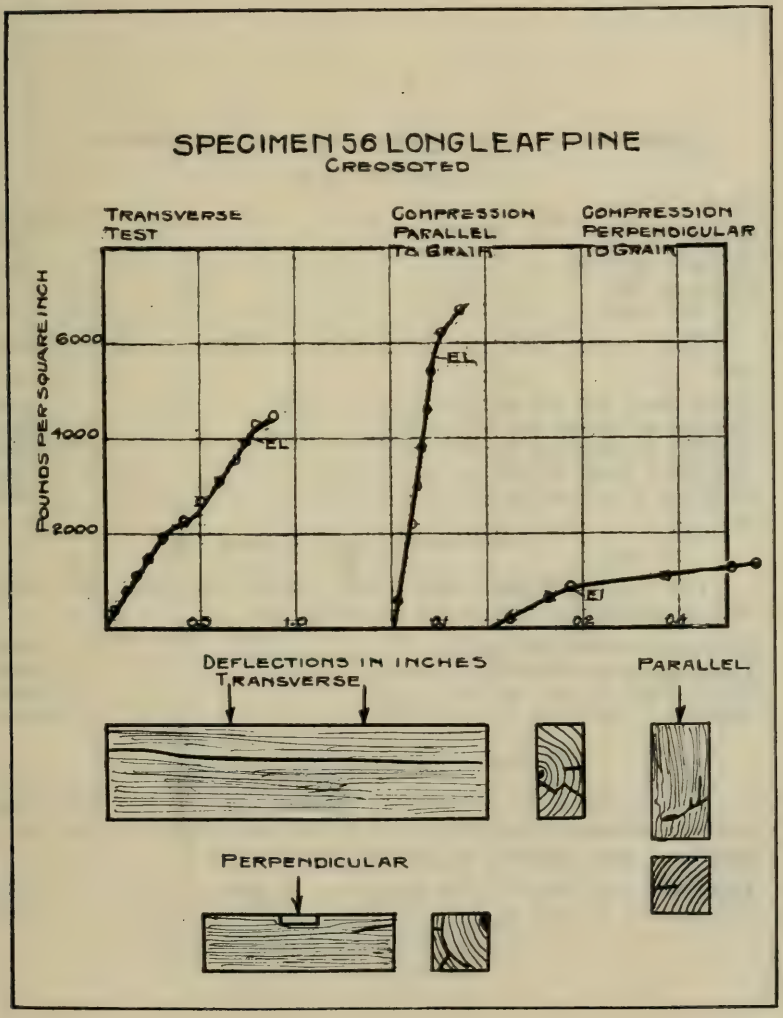
The piece had a knot near the bottom on one side. Failed by shearing from one side into the knot.

Maximum load, lbs. per sq. in	6,698
Deflection at maximum load, inches	0.144
Elastic limit, lbs. per sq. in	5,700
Modulus of elasticity, lbs. per sq. in	690,000

Compression Perpendicular to Grain.

Specimen showed a split on one side near one end. This was the start of failure, then splitting with the year rings across the piece.

Deflection under load of 1,322 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	900


SPECIMEN 56 LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 57—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x7.05
Weight, lbs. per cu. ft.	47.2
Moisture, per cent	55.3
Rings, per inch	13
Sap, per cent	None

This specimen was free from defects. Failure was by horizontal shear.

Elastic limit, lbs. per sq. in	4,300
Modulus of rupture, lbs. per sq. in	4,670
Modulus of elasticity, lbs. per sq. in	1,636,000
Horizontal shear, lbs. per sq. in	395
Deflection at failure, inches	0.94

Compression Parallel to Grain.

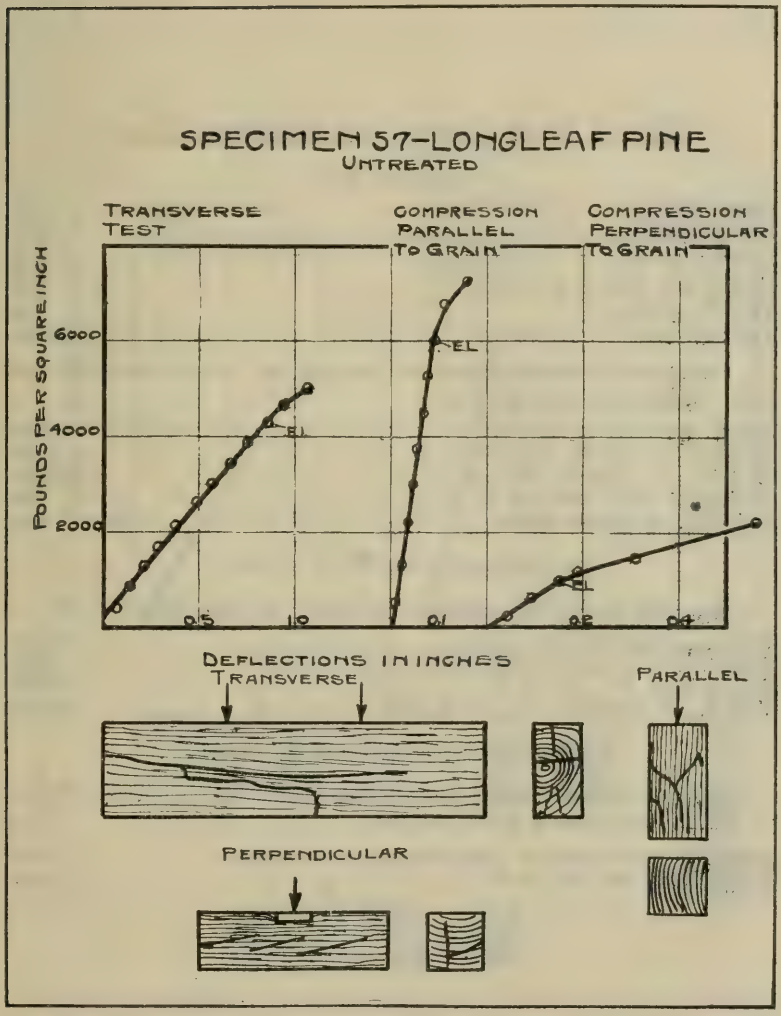
This specimen showed exceptionally regular and strong year rings, with straight grain. Failure was by wedge split.

Maximum load, lbs. per sq. in	7,248
Deflection at maximum load, inches	0.16
Elastic limit, lbs. per sq. in	6,000
Modulus of elasticity, lbs. per sq. in	798,000

Compression Perpendicular to Grain.

This specimen showed sapwood on one side and had three long cracks on opposite side. Piece failed by splitting vertically at one end, a horizontal split extending to the old surface crack.

Deflection under load of 2,253 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,000


SPECIMEN 57—LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 58—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.1x7.0
Weight, lbs. per cu. ft., treated	57.3
Weight, lbs. per cu. ft., untreated	39.3
Weight, lbs. per cu. ft., increase	18.0
Rings, per inch	14
Sap, per cent	None

Piece showed weather check on one end and several knots on one side. Failed in horizontal shear.

Elastic limit, lbs. per sq. in	3,800
Modulus of rupture, lbs. per sq. in	4,990
Modulus of elasticity, lbs. per sq. in	1,880,000
Horizontal shear, lbs. per sq. in	386
Deflection at failure, inches	0.92

Compression Parallel to Grain.

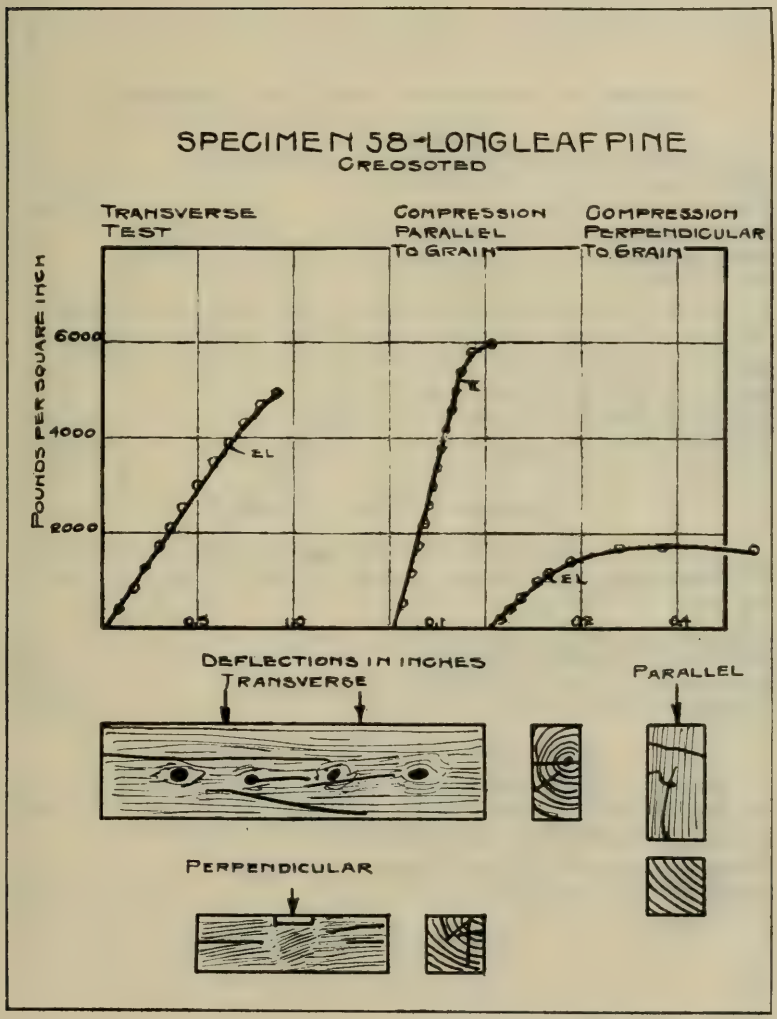
Specimen showed no defects. Failed by shearing near the top.

Maximum load, lbs. per sq. in	5,999
Deflection at maximum load, inches	0.213
Elastic limit, lbs. per sq. in	5,200
Modulus of elasticity, lbs. per sq. in	450,000

Compression Perpendicular to Grain.

Specimen had one lower corner chipped off, but no defects. Failed by splitting horizontally from one end.

Deflection under load of 1,832 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	1,100


SPECIMEN 58-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 59—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.03
Weight, lbs. per cu. ft.	38.3
Moisture, per cent	5.1
Rings, per inch	13
Sap, per cent	7

Specimen had several small knots on one side, and heart shake. Failed by splintering tension, the fracture being below two small knots.

Elastic limit, lbs. per sq. in.	4,600
Modulus of rupture, lbs. per sq. in.	5,540
Modulus of elasticity, lbs. per sq. in.	1,362,000
Horizontal shear, lbs. per sq. in.	433
Deflection at failure, inches	0.141

Compression Parallel to Grain.

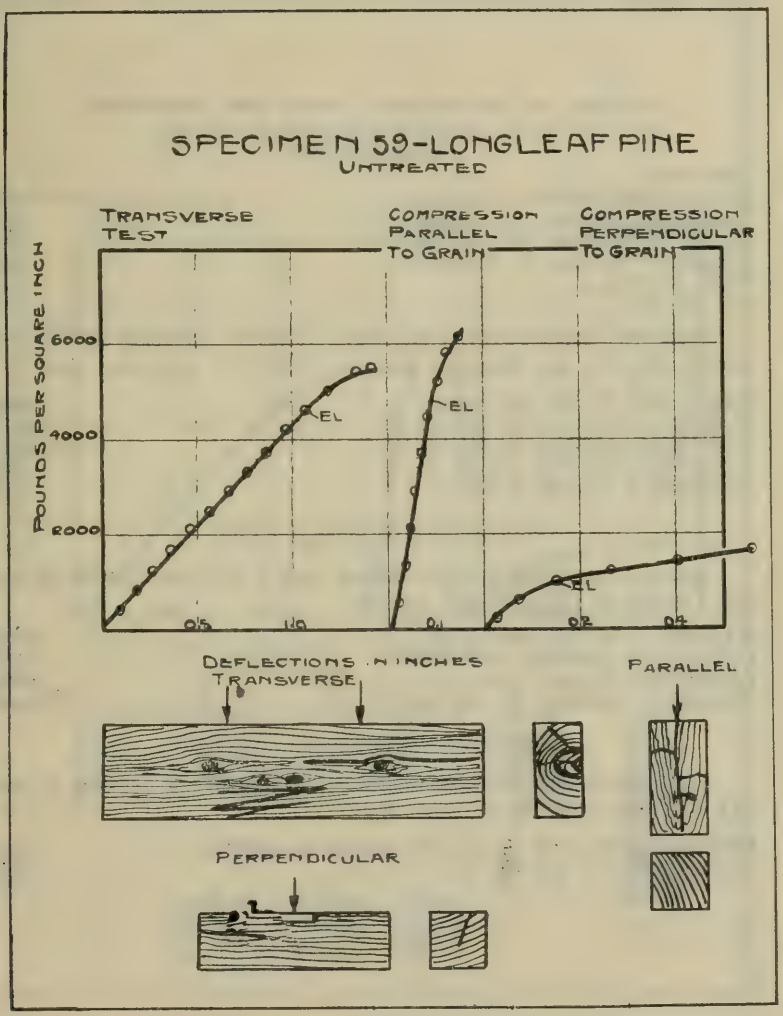
Piece was surface cracked the entire length before loading. Failed by splitting along the crack and crushing outward to sides from split at two points.

Maximum load, lbs. per sq. in.	6,176
Deflection at maximum load, inches	0.15
Elastic limit, lbs. per sq. in.	4,800
Modulus of elasticity, lbs. per sq. in.	618,000

Compression Perpendicular to Grain.

Specimen showed fairly straight grain, with two long cracks on one side. Failed by splitting horizontally and vertically near one end, the horizontal split following an old crack.

Deflection under load of 1,660 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,000


SPECIMEN 59-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
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0.1
0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 60—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.3x7.25
Weight, lbs. per cu. ft., treated	49.2
Weight, lbs. per cu. ft., untreated	38.3
Weight, lbs. per cu. ft., increase	10.9
Rings, per inch	14
Sap, per cent	7

Specimen showed heart shake, with 7 per cent. sapwood on top and bottom, also two pin knots on one side. Failed in horizontal shear.

Elastic limit, lbs. per sq. in	3,400
Modulus of rupture, lbs. per sq. in	5,210
Modulus of elasticity, lbs. per sq. in	1,359,000
Horizontal shear, lbs. per sq. in	409
Deflection at failure, inches	1.44

Compression Parallel to Grain.

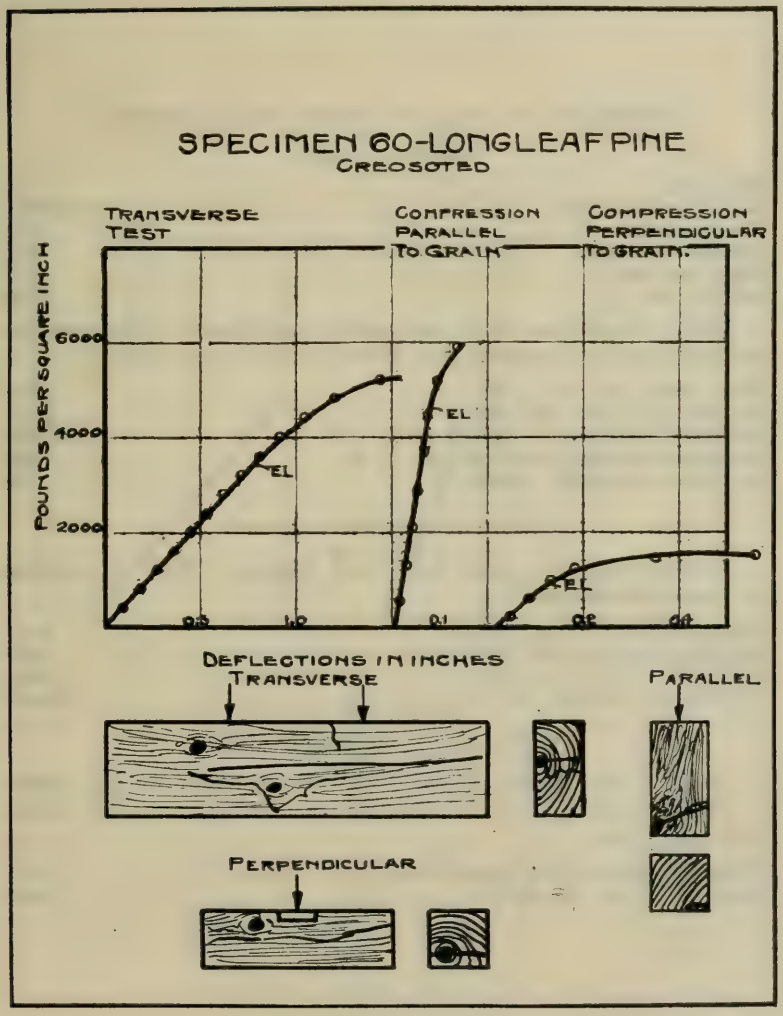
Specimen was fairly straight grained, with a knot near bottom on one side. Failed by shearing near bottom.

Maximum load, lbs. per sq. in	5,876
Deflection at maximum load, inches	0.135
Elastic limit, lbs. per sq. in	4,600
Modulus of elasticity, lbs. per sq. in	693,000

Compression Perpendicular to Grain.

Specimen showed knots on top and sides. Failed by splitting at one end, the split following the year rings.

Deflection under load of 1,537 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	800


SPECIMEN 60-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN.
POUNDS PER SQUARE INCH
6000
4000
2000
EL
EL
EL
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 61—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x6.91
Weight, lbs. per cu. ft.	42.7
Moisture, per cent	16.7
Rings, per inch	9
Sap, per cent	None

Piece showed heart shake and several small knots. Failure was by splintering tension, apparently not affected by any visible defects.

Elastic limit, lbs. per sq. in.	4,600
Modulus of rupture, lbs. per sq. in.	4,790
Modulus of elasticity, lbs. per sq. in.	1,542,000
Maximum horizontal shear, lbs. per sq. in.	408
Deflection at failure, inches	1.0

Compression Parallel to Grain.

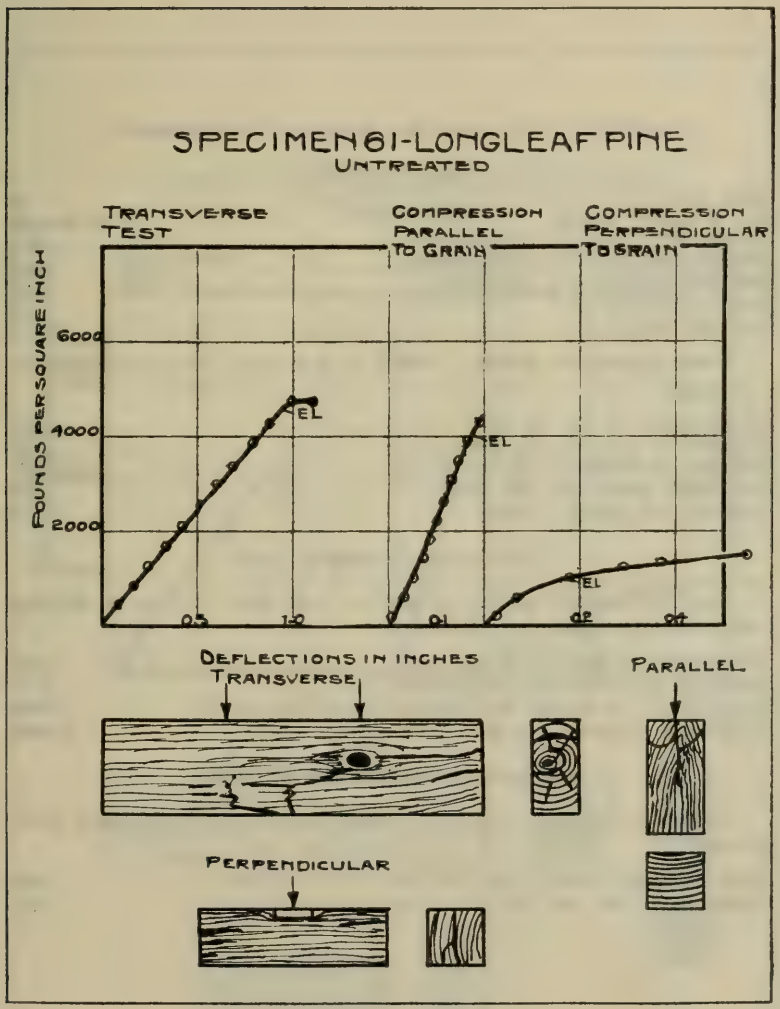
Specimen had two large knots near bottom. Failed by crushing near top and splitting.

Maximum load, lbs. per sq. in.	4,343
Deflection at maximum load, inches	0.19
Elastic limit, lbs. per sq. in.	4,000
Modulus of elasticity, lbs. per sq. in.	283,000

Compression Perpendicular to Grain.

Specimen was straight grained, with two small knots on top. Failed by splitting horizontally from both ends and vertically through center from both sides.

Deflection under load of 1,536 lbs. per sq. in., inches	0.55
Elastic limit, lbs. per sq. in.	1,000


SPECIMEN 61-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
EL
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0.5
1.0
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0.2
0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 62—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.18x7.06
Weight, lbs. per cu. ft., treated	58.6
Weight, lbs. per cu. ft., untreated	45.8
Weight, lbs. per cu. ft., increase	12.8
Rings, per inch	14
Sap, per cent	None

Piece showed no defects. Failed by horizontal shear following the year rings.

Elastic limit, lbs. per sq. in.	3,800
Modulus of rupture, lbs. per sq. in.	4,390
Modulus of elasticity, lbs. per sq. in.	1,629,000
Horizontal shear, lbs. per sq. in.	420
Deflection at failure, inches	0.92

Compression Parallel to Grain.

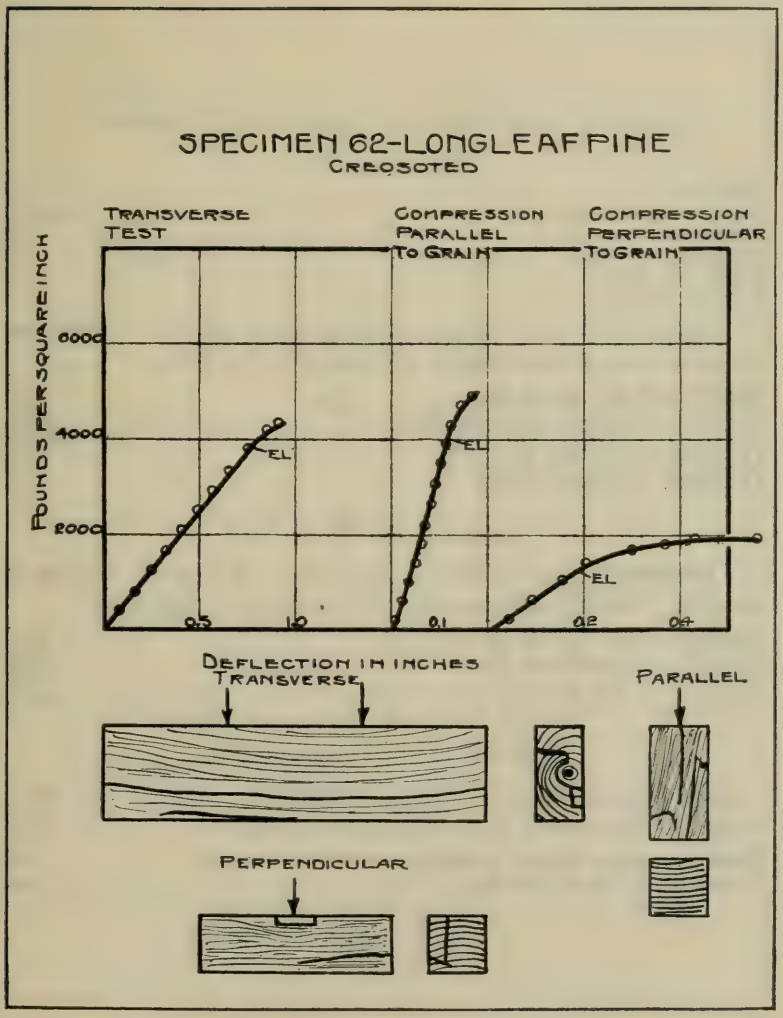
Specimen showed knot near edge on two sides. Failed by splitting and crushing to edge through knot.

Maximum load, lbs. per sq. in.	4,906
Deflection at maximum load, inches	0.17
Elastic limit, lbs. per sq. in.	4,000
Modulus of elasticity, lbs. per sq. in.	405,000

Compression Perpendicular to Grain.

Specimen showed no defects. Failed by splitting horizontally from one end.

Deflection under load of 1,963 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in.	1,300


SPECIMEN 62-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
4000
2000
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EL
EL
0.5
1.0
0.1
0.2
0.4
DEFLECTION IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 63—LONG-LEAF YELLOW PINE (UNTREATED).

Transverse Test.

Span, feet	13
Size at center, inches	16.0x7.25
Weight, lbs. per cu. ft	39.2
Moisture, per cent	16.9
Rings, per inch	14
Sap, per cent	2

The specimen had five large sound knots on one side. Failure was caused by cross-grained tension, and was around a knot.

Elastic limit, lbs. per sq. in	4,700
Modulus of rupture, lbs. per sq. in	4,985
Modulus of elasticity, lbs. per sq. in	1,322,000
Horizontal shear, lbs. per sq. in	375
Deflection at failure, inches	1.24

Compression Parallel to Grain.

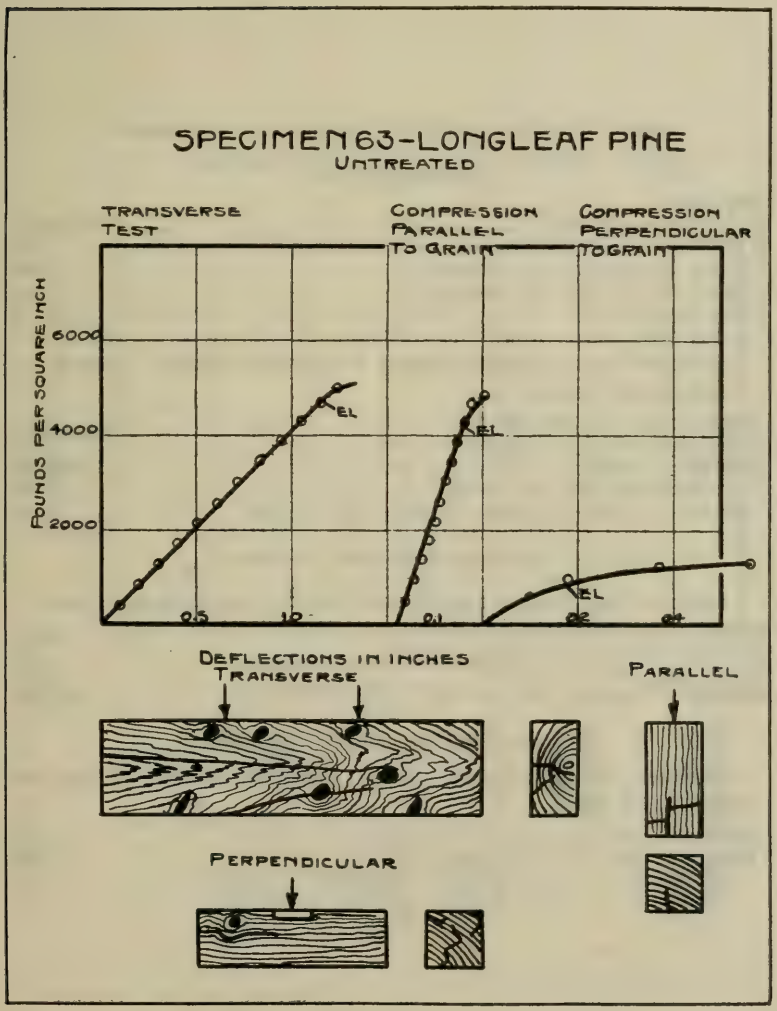
The piece showed an irregular grain and a short crack near top on one side. Failed by splitting and crushing near the bottom.

Maximum load, lbs. per sq. in	4,856
Deflection at maximum load, inches	0.205
Elastic limit, lbs. per sq. in	4,200
Modulus of elasticity, lbs. per sq. in	316,500

Compression Perpendicular to Grain.

Specimen showed a small solid knot on one side, near one end. Failed by splitting horizontally from this end under the knot.

Deflection under load of 1,368 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	900


SPECIMEN 63-LONGLEAF PINE
UNTREATED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
6000
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DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMEN NO. 64—LONG-LEAF YELLOW PINE (CREOSOTED).

Transverse Test.

Span, feet	13
Size at center, inches	16.25x7.36
Weight, lbs. per cu. ft., treated	51.1
Weight, lbs. per cu. ft., untreated	36.4
Weight, lbs. per cu. ft., increase	14.7
Rings, per inch	15
Sap, per cent	2

Specimen was top timber having several large knots. Failure was by cross-grained tension.

Elastic limit, lbs. per sq. in	2,420
Modulus of rupture, lbs. per sq. in	3,737
Modulus of elasticity, lbs. per sq. in	1,055,000
Horizontal shear, lbs. per sq. in	365
Deflection at time of failure, inches	1.4

Compression Parallel to Grain.

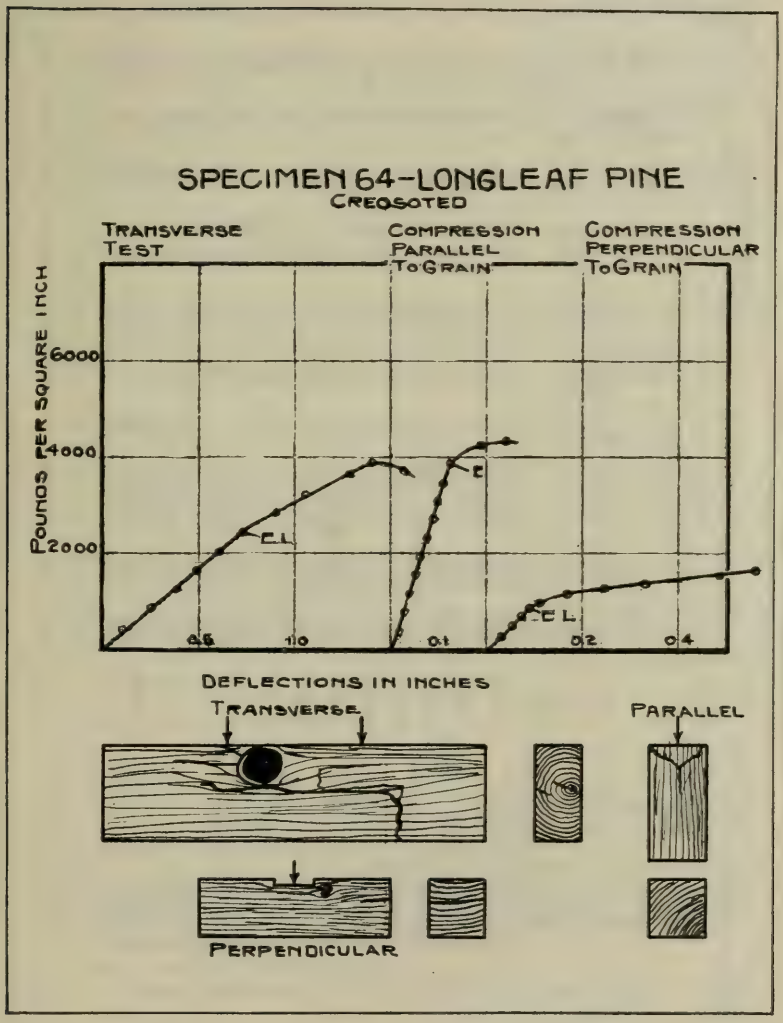
Specimen was straight grained, and failed at top by wedge shear.

Maximum load, lbs. per sq. in	4,292
Deflection at maximum load, inches	0.24
Elastic limit, lbs. per sq. in	3,850
Modulus of elasticity, lbs. per sq. in	367,000

Compression Perpendicular to Grain.

Specimen had several large knots. Failed by splitting to end and crushing under plate.

Deflection under load of 2,425 lbs. per sq. in., inches	0.56
Elastic limit, lbs. per sq. in	850


SPECIMEN 64-LONGLEAF PINE
CREOSOTED
TRANSVERSE TEST
COMPRESSION PARALLEL TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN
POUNDS PER SQUARE INCH
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0.4
DEFLECTIONS IN INCHES
TRANSVERSE
PARALLEL
PERPENDICULAR

SPECIMENS TESTED IN 1911.

GENERAL DATA								TRANSVERSE TEST					COMPRESSION PARALLEL TO GRAIN				COMPRESSION PERPENDICULAR TO GRAIN			
																		Load in Lbs. per sq. in. for Deflection of		
Specimen Number	Weight in Lbs. per Cu. Ft. Before Treating	Weight in Lbs. per Cu. Ft. After Treating	Moisture Per Cent.	Rings, per inch	Size at Center Inches	General Character	Remarks	Elastic Limit Lbs. per sq. in.	Modulus of Rupture Lbs. per sq. in.	Modulus of Elasticity Lbs. per sq. in.	Deflection at Failure Inches	Maximum Horizontal Shear Lbs. per sq. in.	Elastic Limit Lbs. per sq. in.	Modulus of Elasticity Lbs. per sq. in.	Maximum Load Lbs. per sq. in.	Deflection for 2000 Lbs. per sq. in.	Elastic Limit Lbs. per sq. in.	1-10 inch	3-16 inch	3-8 inch
11	41.5	.....	17.1	17	16.20x7.05	Knotty	.....	3800	4980	1,429,000	0.82	387	3400	343,960	3996	0.07	900	700	900	1300
12	39.1	50.6	.....	17	16.40x7.19	Knotty	Treated	4200	5560	1,395,000	1.78	439	4700	707,410	5829	0.04	1100	700	1100	1400
17	43.8	.....	20.4	13	16.20x7.20	Clear	.....	2800	3880	1,882,000	1.38	410	5600	840,000	6397	0.03	1400	950	1600	2150
18	40.5	61.8	.....	10	16.00x7.00	Clear	Treated	5000	5050	1,749,000	0.93	388	4800	346,500	5279	0.08	1100	850	1300	1800
21	38.9	.....	16.6	12	16.12x7.05	Small Knots	.....	5000	6800	1,517,000	1.75	528	4200	385,000	4668	0.07	1500	1000	1700	2050
22	42.2	55.2	.....	12	16.00x7.10	.....	Treated	5400	5410	1,428,000	1.24	416	4300	556,850	5228	0.05	900	900	1200	1450
25	42.4	.....	15.1	19	16.00x7.11	Small Knots	.....	5800	6280	1,876,000	1.14	483	5700	758,720	6353	0.04	1200	700	1300	1850
26	46.5	57.5	.....	19	16.10x7.15	.....	Treated	4600	4880	1,600,000	1.00	378	5800	580,000	6860	0.05	1800	800	1400	2300
27	38.9	.....	16.7	8	16.25x7.22	Sapwood	.....	3900	4500	1,505,000	0.98	352	5500	665,500	6754	0.05	900	550	900	1300
28	44.5	57.8	.....	8	16.20x7.08	Small Knots	Treated	3100	3280	1,417,000	0.70	374	5300	706,660	6064	0.04	1000	900	1250	1600
29	38.4	.....	13.5	8	16.06x6.98	Small Knots	.....	5000	6160	1,612,000	1.40	468	5000	666,000	6126	0.04	1400	600	1050	1500
30	41.3	60.5	.....	8	16.10x7.14	Small Knots	Treated	4800	6320	1,715,000	1.30	498	4800	720,000	5784	0.04	1000	750	1100	1500
35	39.5	.....	20.6	6	16.25x7.18	.....	.....	3800	5100	1,344,000	1.34	399	4600	693,000	5473	0.03	900	700	950	1400
36	42.9	55.0	.....	6	16.25x7.11	Small Knots	Treated	5400	6040	1,639,000	1.19	467	4300	275,000	4595	0.09	900	600	900	1200
51	40.3	.....	8.5	9	16.25x7.42	Small Knots	.....	3600	4000	1,435,000	0.91	348	3100	464,000	3951	0.05	800	850	1100	1250
52	38.3	49.9	.....	9	16.60x7.35	Small Knots	Treated	3400	4160	1,718,000	1.16	332	4000	574,000	5177	0.04	800	650	900	1300
53	36.8	.....	13.7	20	15.90x7.10	Small Knots	.....	3800	4880	1,904,000	0.92	373	6200	786,000	7040	0.04	700	500	850	1100
54	37.8	48.5	.....	20	16.00x7.10	Wane	Treated	4200	4900	1,600,000	1.04	410	4400	664,000	5172	0.04	800	400	700	1150
55	47.7	.....	18.6	11	16.36x7.22	Knotty	.....	4400	5500	1,688,000	1.13	432	5800	772,000	6301	0.04	1100	650	1000	1550
56	50.7	59.8	.....	11	16.60x7.25	Shake	Treated	4000	4460	1,670,000	0.87	387	5700	690,000	6698	0.04	900	500	900	1150
57	47.2	.....	55.3	13	16.00x7.05	Clear	.....	4300	4670	1,636,000	0.94	395	6000	798,000	7248	0.04	1000	650	1100	1700
58	39.3	57.3	.....	14	16.10x7.00	Small Knots	Treated	3800	4990	1,880,000	0.92	386	5200	450,000	5999	0.06	1100	900	1400	1750
59	38.3	.....	5.1	13	16.25x7.03	Small Knots	.....	4600	5540	1,362,000	1.41	433	4800	618,000	6176	0.05	1000	800	1100	1400
60	38.3	49.2	.....	14	16.30x7.25	Cross Grain	Treated	3400	5210	1,359,000	1.44	409	4600	693,000	5876	0.04	800	700	1150	1550
61	42.7	.....	16.7	9	16.25x6.91	Heart Shake	.....	4600	4790	1,542,000	1.00	408	4000	283,000	4343	0.09	1000	800	1000	1300
62	45.8	58.6	.....	9	16.18x7.06	Clear	Treated	3800	4390	1,629,000	0.92	420	4000	405,000	4906	0.06	1300	600	1200	1850
Average Untreated								4260	5160	1,595,000	1.15	415	4920	621,000	5750	0.049	1031	727	1120	1530
Average Treated								4240	4980	1,600,000	1.12	408	4770	568,000	5650	0.052	1040	711	1107	1540

NOTE: Odd number is the untreated half of a stringer and the following even number is the treated half.

SPECIMENS TESTED IN 1912

Specimen Number	GENERAL DATA: Weight in Lbs. per Cu. Ft. Before Treating	Weight in Lbs. per Cu. Ft. After Treating	Weight in Lbs. per Cu. Ft. One Year After Treating	Moisture Per Cent.	Rings, per inch	Size at Center Inches	General Character	Remarks	TRANSVERSE TEST: Elastic Limit Lbs. per sq. in.	Modulus of Rupture Lbs. per sq. in.	Modulus of Elasticity Lbs. per sq. in.	Deflection at Failure Inches	Maximum Horizontal Shear Lbs. per sq. in.	COMPRESSION PARALLEL TO GRAIN: Elastic Limit Lbs. per sq. in.	Modulus of Elasticity Lbs. per sq. in.	Maximum Load Lbs. per sq. in.	Deflection for 2000 Lbs. per sq. in.	COMPRESSION PERPENDICULAR TO GRAIN: Elastic Limit Lbs. per sq. in.	Load in Lbs. per Square Inch for Deflection of 1-10 inch	Load in Lbs. per Square Inch for Deflection of 3-16 inch	Load in Lbs. per Square Inch for Deflection of 3-8 inch
1	42.2	.....	.....	18.2	8	16.00x6.68	Knots	.....	5000	5290	1,850,000	0.93	407	4200	360,000	6510	0.060	1100	925	1150	1625
2	43.8	54.4	50.4	.....	8	16.19x7.06	Checks	Treated	4775	6016	1,840,000	0.70	467	6000	630,000	7143	0.045	800	1000	1150	1400
5	45.5	.....	.....	18.5	8	16.30x6.97	Shakes	.....	4200	4880	1,480,000	1.24	383	5100	386,000	5904	0.072	1100	875	1400	1950
6	38 8	50.6	46.3	.....	8	16.40x7.24	Checks	Treated	4400	4517	1,380,000	1.12	356	5720	575,000	6460	0.042	700	1000	1100	1350
7	38.5	.....	.....	18.1	8	16.25x7.31	Knots	.....	4000	4760	1,416,000	1.40	372	4000	585,750	5070	0.040	1000	700	1050	1400
8	44.5	56.2	54.8	.....	8	16.13x7.38	Shakes	Treated	4600	6658	1,640,000	1.68	505	5400	648,000	5997	0.041	625	800	1050	1450
9	42.9	.....	.....	17.8	19	15.95x7.14	Knots	.....	5400	5480	1,591,000	1.22	448	5800	842,450	6571	0.035	1000	700	1050	1500
10	46.1	60.2	54.3	.....	19	16.00x7.10	Shakes	Treated	6000	6006	1,807,000	1.07	462	5800	703,000	6951	0.037	550	700	800	1000
15	46.2	.....	.....	18.4	7	16.20x7.20	Knots	.....	1800	4870	1,918,000	1.60	367	7300	674,000	7410	0.037	900	900	1200	1600
16	42.3	56.2	51.8	.....	7	16.30x7.55	Large Knots	Treated	3900	4406	1,690,000	1.03	346	5500	474,000	6263	0.052	700	900	1100	1350
19	45.8	.....	.....	8.5	21	16.25x7.11	Knots	.....	2000	3820	1,820,000	1.28	384	5200	451,300	5659	0.063	1100	625	1050	1650
20	49.6	58.5	52.1	.....	21	16.25x7.25	Shakes	Treated	4325	4477	1,875,000	0.72	350	6200	835,000	7721	0.038	1400	1000	1675	2275
23	45.8	.....	.....	19.0	10	16.50x7.07	Small Knots	.....	3800	4050	1,254,000	0.97	322	4600	551,310	5569	0.042	1000	675	1150	1550
24	37.2	52.2	52.2	.....	10	16.75x7.18	Shakes	Treated	3500	4850	1,206,000	1.39	392	5080	584,400	6410	0.044	1000	1000	1400	1825
31	47.1	.....	.....	16.4	14	16.00x7.17	Small Knots	.....	4000	5440	1,726,000	1.15	419	5600	423,000	6253	0.059	.....	.....	.....	.....
32	51.3	58.3	56.8	.....	14	16.87x6.94	Cross Grain	Treated	5100	5294	1,632,000	0.94	430	7000	736,000	7768	0.031	.....	.....	.....	.....
33	41.8	.....	.....	19.3	15	16.00x7.23	Knots	.....	4200	5390	2,660,000	1.21	415	5300	426,000	5918	0.062	900	700	1000	1300
34	45.5	64.2	61.4	.....	15	16.00x7.15	Checks	Treated	4425	6049	1,910,000	0.74	465	6300	711,000	6945	0.040	1250	1300	1600	2450
37	38.3	.....	.....	18.0	12	16.12x7.24	Knots	.....	2900	3410	1,034,000	1.40	265	3700	633,000	4720	0.041	900	450	900	1300
38	36.2	51.8	51.0	.....	12	16.25x7.32	Large Knots	Treated	4100	4035	1,090,000	1.20	315	5200	719,000	6012	0.037	1200	1400	1525	1750
41	41.8	.....	.....	35.6	6	16.60x7.37	Clear	.....	4500	4840	1,652,000	0.92	386	5500	734,000	6580	0.034	1200	500	900	1600
42	38.7	55.1	48 8	.....	6	16.25x7.38	Clear	Treated	4700	4800	1,576,000	0.99	375	3500	526,000	5604	0.048	1000	1000	1400	1750
43	43.0	.....	.....	18.3	17	16.20x7.35	Shakes	.....	2600	3640	1,433,000	0.88	263	5000	432,000	6063	0.060	900	600	850	1275
44	49.2	56.3	54.6	.....	17	16.10x7.15	Cross Grain	Treated	4700	6737	1,542,000	0.96	520	5800	776,000	6656	0.038	700	800	1050	1475
45	39.0	.....	.....	17.2	11	16.00x6.75	Pitch Pocket	.....	4800	6060	1,808,000	1.16	466	4700	380,000	5492	0.041	900	700	1000	1400
46	38.4	54.2	46.4	.....	11	16.25x7.24	Clear	Treated	2800	4014	1,416,000	0.62	314	5300	653,000	5759	0.041	1350	1300	1650	2250
47	37.5	.....	.....	6.2	10	16.20x7.19	Warped	.....	3500	3900	1,454,000	0.93	341	5400	720,000	6450	0.039	1100	600	1050	1600
48	41.6	55.4	46.8	.....	10	16.37x7.13	Cross Grain	Treated	3250	5312	1,470,000	2.90	412	6400	646,000	6905	0.040	800	950	1150	1400
49	38.4	.....	.....	18.0	7	16.00x7.15	Small Knots	.....	4200	5200	1,511,000	1.28	400	5600	558,000	6310	0.045	700	700	1050	1300
50	42.3	58.1	55.8	.....	7	16.06x7.09	Checks	Treated	5900	7114	1,586,000	1.20	550	5800	539,000	6150	0.050	1400	800	2350	2750
63	39.2	.....	.....	16.9	15	16.00x7.25	Large Knots	.....	4700	4985	1,322,000	1.24	375	4200	316,500	4856	0.085	1000	600	1000	1200
64	36.4	52.4	51.1	.....	15	16.25x7.36	Large Knots	Treated	2420	3737	1,055,000	1.40	365	3850	367,000	4292	0.064	850	900	1200	1400
Average Untreated									3850	4750	1,554,300	1.18	377	5075	529,400	5958	0.051	986	684	1052	1483
Average Treated									4305	5263	1,544,700	1.17	414	5553	633,000	6440	0.041	945	1056	1340	1691

NOTE: Odd number is the untreated half of a stringer and the following even number is the treated half.

SPECIAL TEST—SPECIMENS NOS. 13 AND 14 (UNTREATED).

General Data.

	13 (Top End)	14 (Butt End)
Size at center, inches	16.25x7.25	16.37x7.44
Weight, lbs. per cu. ft.	38.8	38.9
Moisture, per cent.	15.3	17.5
Rings, per inch	15	12
Character of wood	Knotty	Clear

Transverse Test.

Elastic limit, lbs. per sq. in.	3,700	4,400
Modulus of rupture, lbs. per sq. in.	3,670	4,920
Modulus of elasticity, lbs. per sq. in.	1,310,000	1,427,000
Horizontal shear, lbs. per sq. in.	318	390
Deflection at failure, inches	0.92	1.14

Compression Parallel to Grain.

Elastic limit, lbs. per sq. in.	3,800	5,400
Modulus of elasticity, lbs. per sq. in.	568,100	619,110
Maximum load, lbs. per sq. in.	4,806	5,880
Deflection for load of 2,000 lbs. per sq. in., inches	0.04	0.04

Compression Perpendicular to Grain.

Elastic limit, lbs. per sq. in.	900	1,000
Load for deflection of 1/10 inch, lbs. per sq. in.	800	750
Load for deflection of 3/16 inch, lbs. per sq. in.	1,300	1,100
Load for deflection of ⅜ inch, lbs. per sq. in.	1,600	1,450

SPECIAL TEST—SPECIMENS NOS. 39 AND 40 (CREOSOTED).

General Data.

	40 (Top End)	39 (Butt End)
Size at center, inches	16.1x7.1	16.35x7.25
Weight, lbs. per cu. ft., treated	57.0	56.8
Weight, lbs. per cu. ft., untreated	41.1	44.1
Weight, lbs. per cu. ft., increase	15.9	12.7
Rings, per inch	15	15
Character of wood	Clear	Clear

Transverse Test.

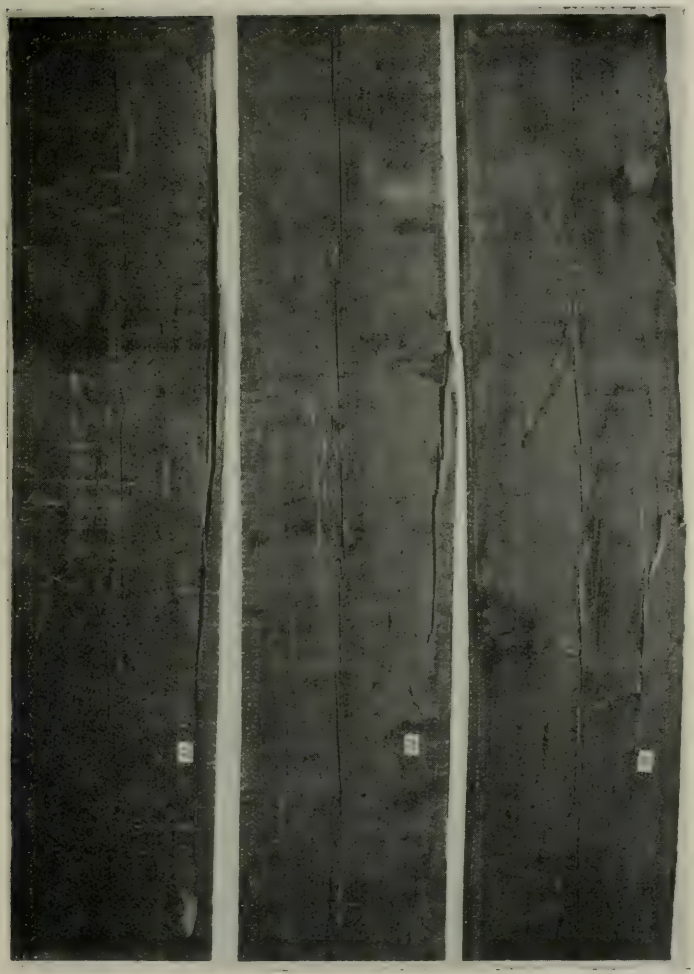
Elastic limit, lbs. per sq. in.	4,400	4,900
Modulus of rupture, lbs. per sq. in.	4,660	5,635
Modulus of elasticity, lbs. per sq. in.	1,623,000	1,632,000
Horizontal shear, lbs. per sq. in.	393	442
Deflection at failure, inches	0.94	1.11

Compression Parallel to Grain.

Elastic limit, lbs. per sq. in.	5,300	5,200
Modulus of elasticity, lbs. per sq. in.	704,000	779,000
Maximum load, lbs. per sq. in.	6,002	6,052
Deflection for load of 2,000 lbs. per sq. in., inches	0.04	0.03

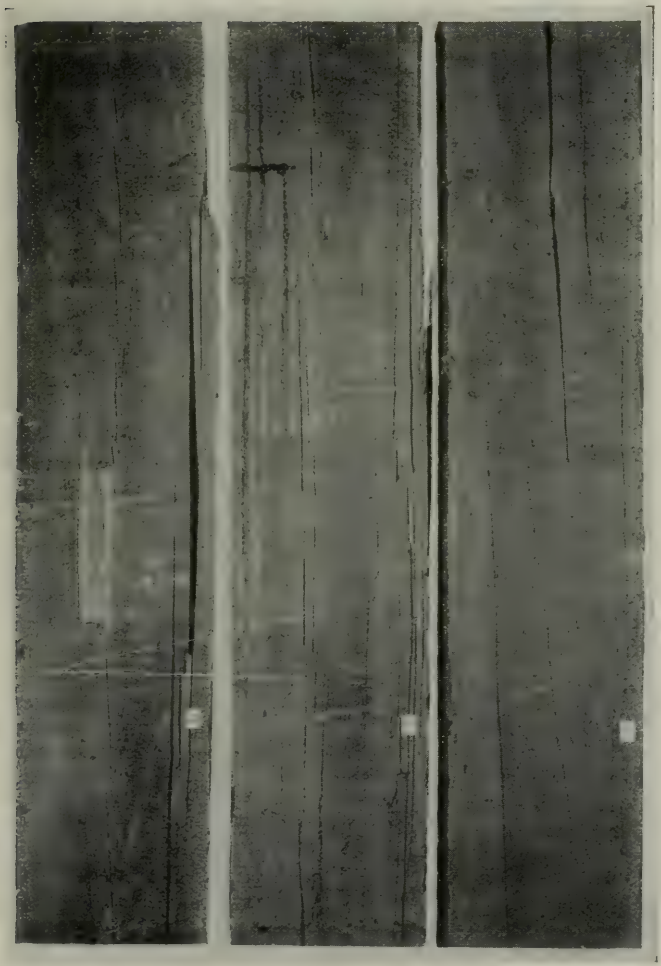
Compression Perpendicular to Grain.

Elastic limit, lbs. per sq. in.	800	800
Load for deflection of 1/10 inch, lbs. per sq. in.	650	750
Load for deflection of 3/16 inch, lbs. per sq. in.	950	1,150
Load for deflection of ⅜ inch, lbs. per sq. in.	1,350	1,550

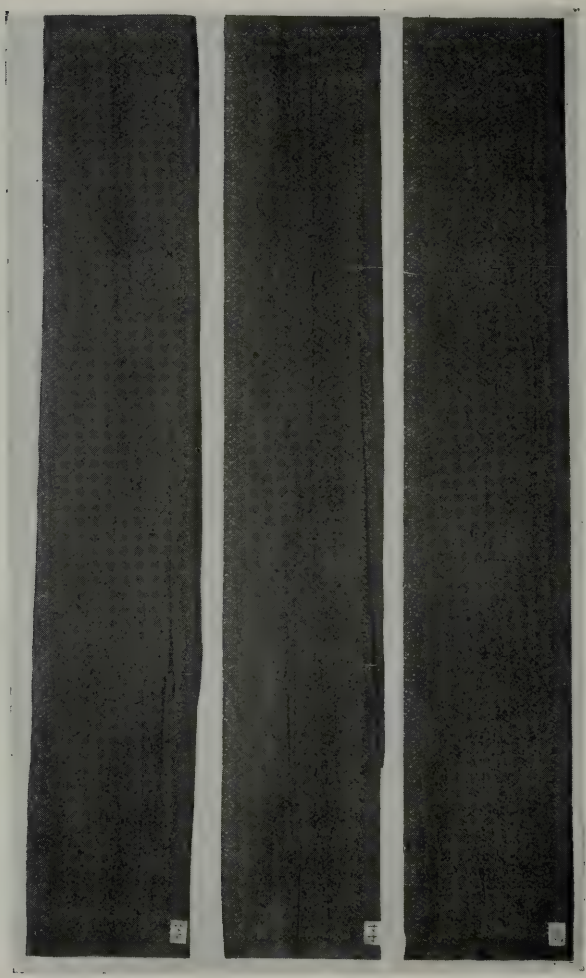


CENTRAL PORTIONS OF UNTREATED SPECIMENS AFTER TRANSVERSE TEST. TESTED JANUARY, 1911.

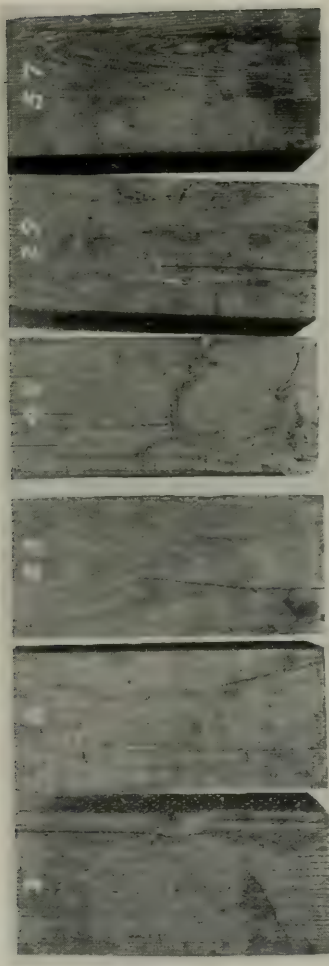
CENTRAL PORTIONS OF TREATED SPECIMENS AFTER TRANSVERSE TEST. SPECIMENS TESTED JANUARY, 1911, IMMEDIATELY AFTER TREATMENT.



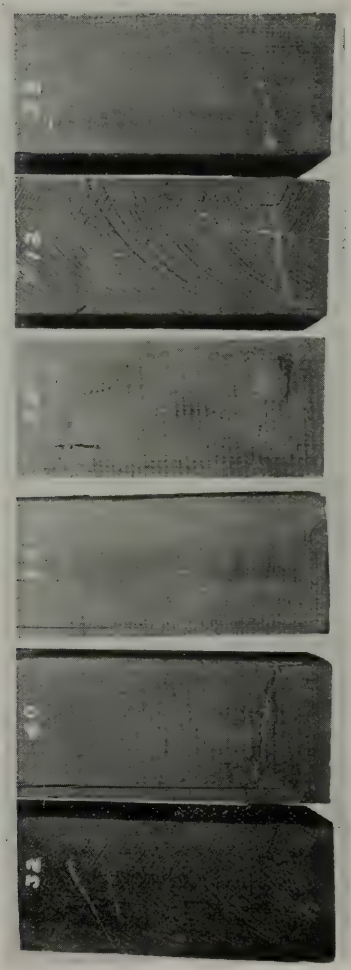
CENTRAL PORTIONS OF TREATED SPECIMENS AFTER TRANSVERSE TEST. SPECIMENS TESTED JANUARY, 1911, IMMEDIATELY AFTER TREATMENT.



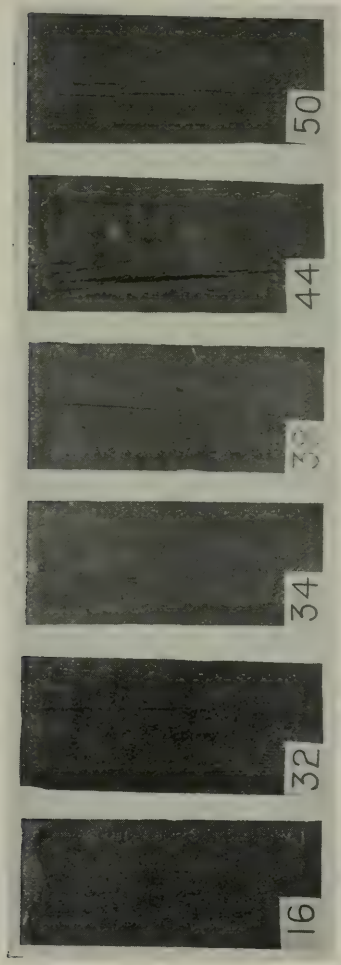
CENTRAL PORTIONS OF TREATED SPECIMENS AFTER TRANSVERSE TEST. SPECIMENS TESTED JANUARY, 1912, ONE YEAR AFTER TREATMENT.



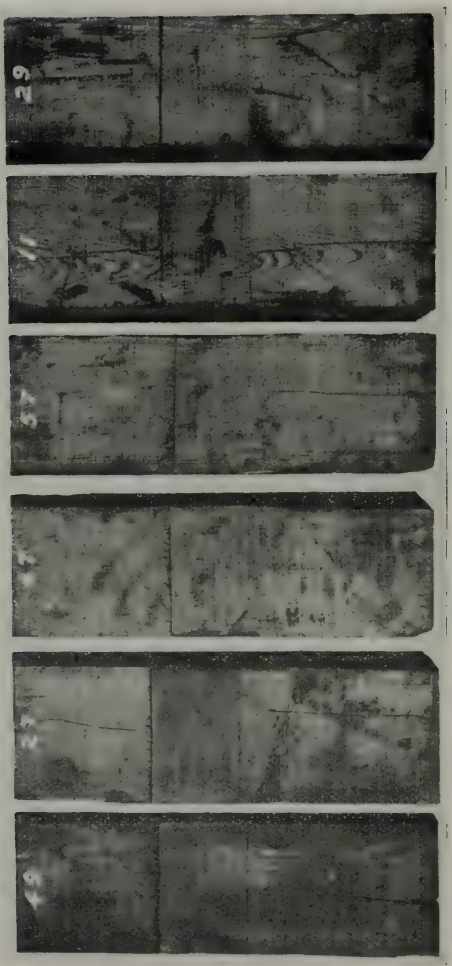
UNTREATED SPECIMENS SHOWING FAILURE IN TEST PARALLEL TO GRAIN.
JANUARY, 1911, TEST.



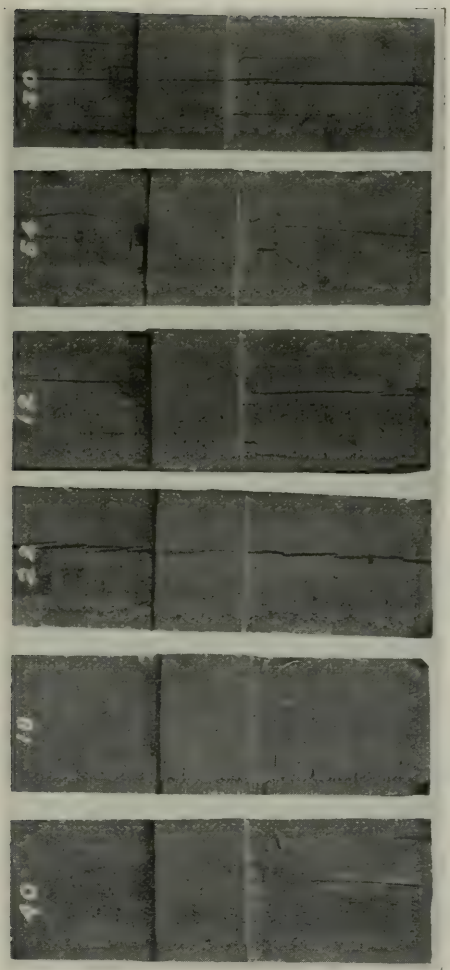
FAILURE OF TREATED SPECIMENS IN COMPRESSION PARALLEL TO THE GRAIN TEST. SPECIMENS WERE TESTED IN JANUARY 1911, IMMEDIATELY AFTER TREATMENT.



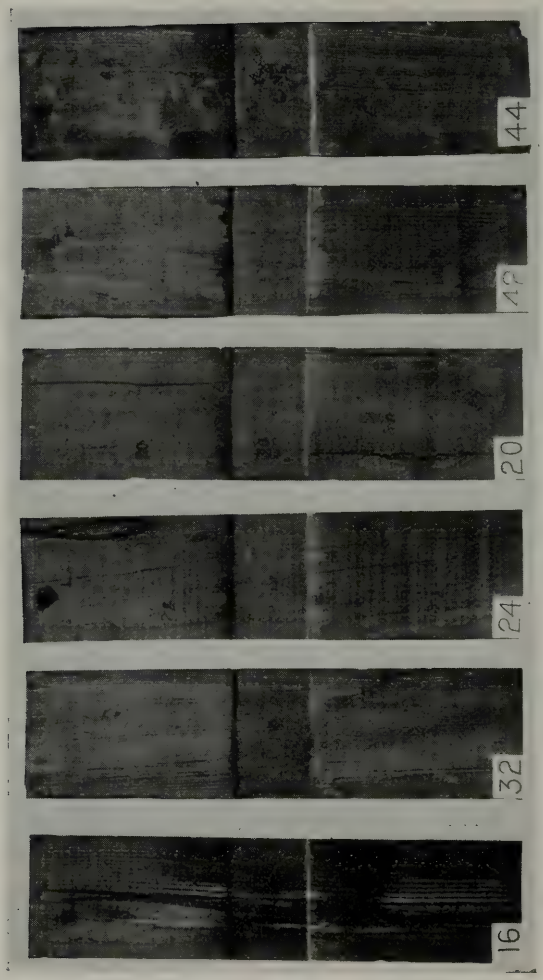
FAILURE OF TREATED SPECIMENS IN COMPRESSION PARALLEL TO THE GRAIN
TEST. SPECIMENS WERE TREATED IN JANUARY, 1912,
ONE YEAR AFTER TREATMENT.



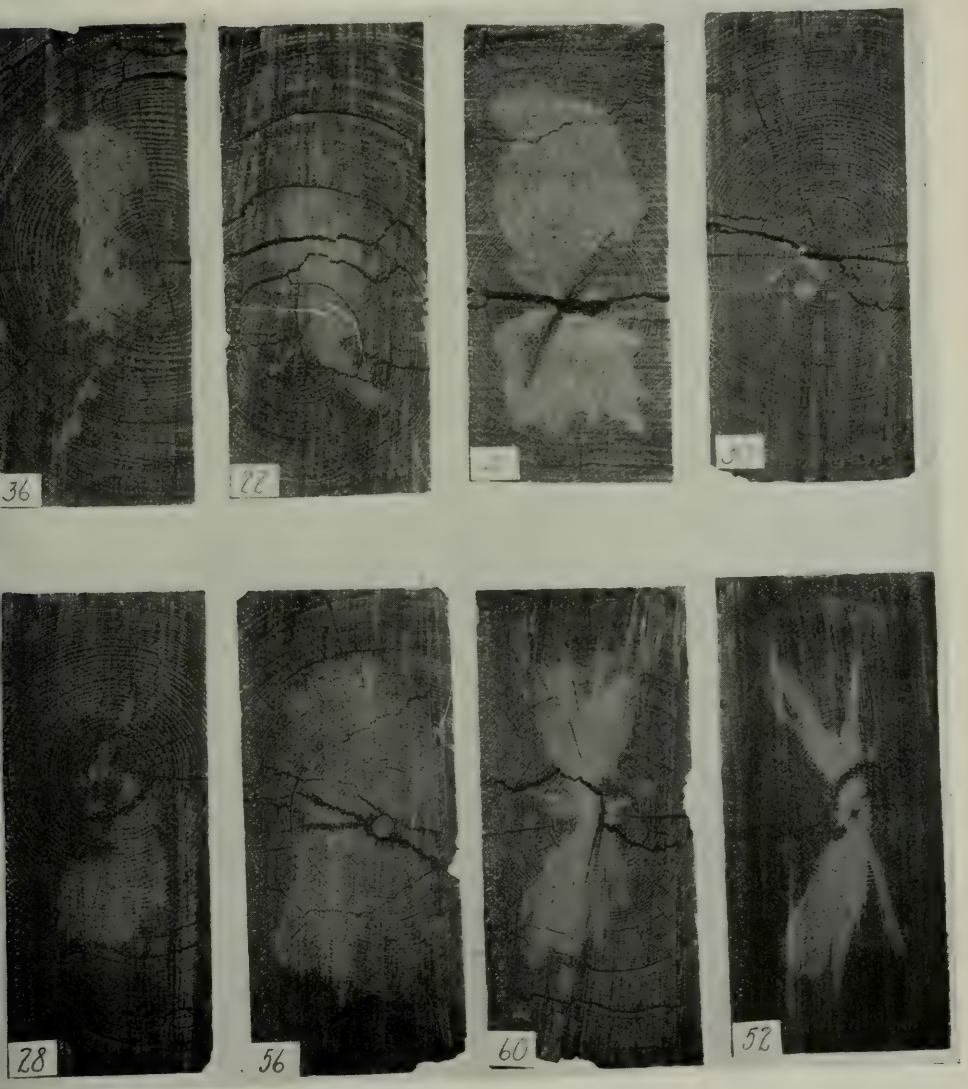
FAILURE OF UNTREATED SPECIMENS IN COMPRESSION PERPENDICULAR TO THE GRAIN TEST. SPECIMENS WERE TESTED IN JANUARY, 1912, IMMEDIATELY AFTER TREATMENT.



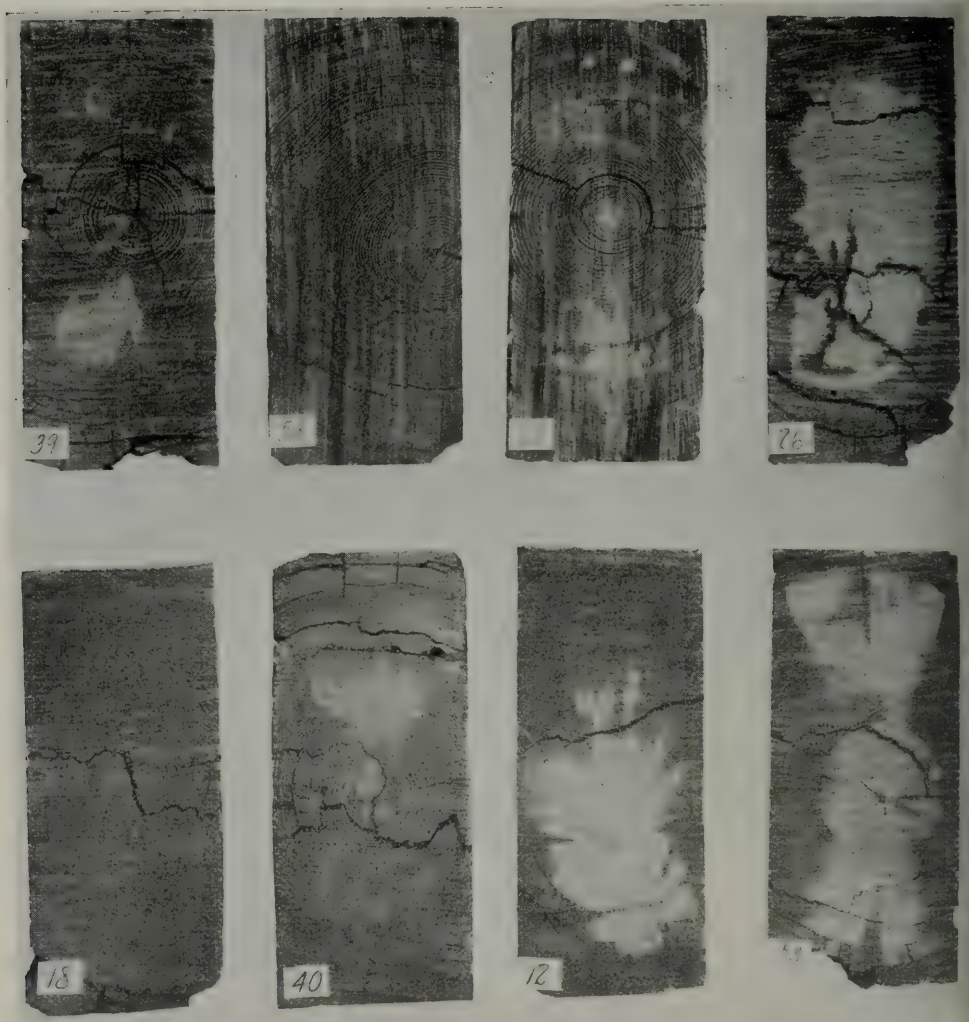
FAILURE OF TREATED SPECIMEN IN COMPRESSION PERPENDICULAR TO THE GRAIN TEST. SPECIMENS WERE TESTED IN JANUARY, 1911, IMMEDIATELY AFTER TREATMENT.



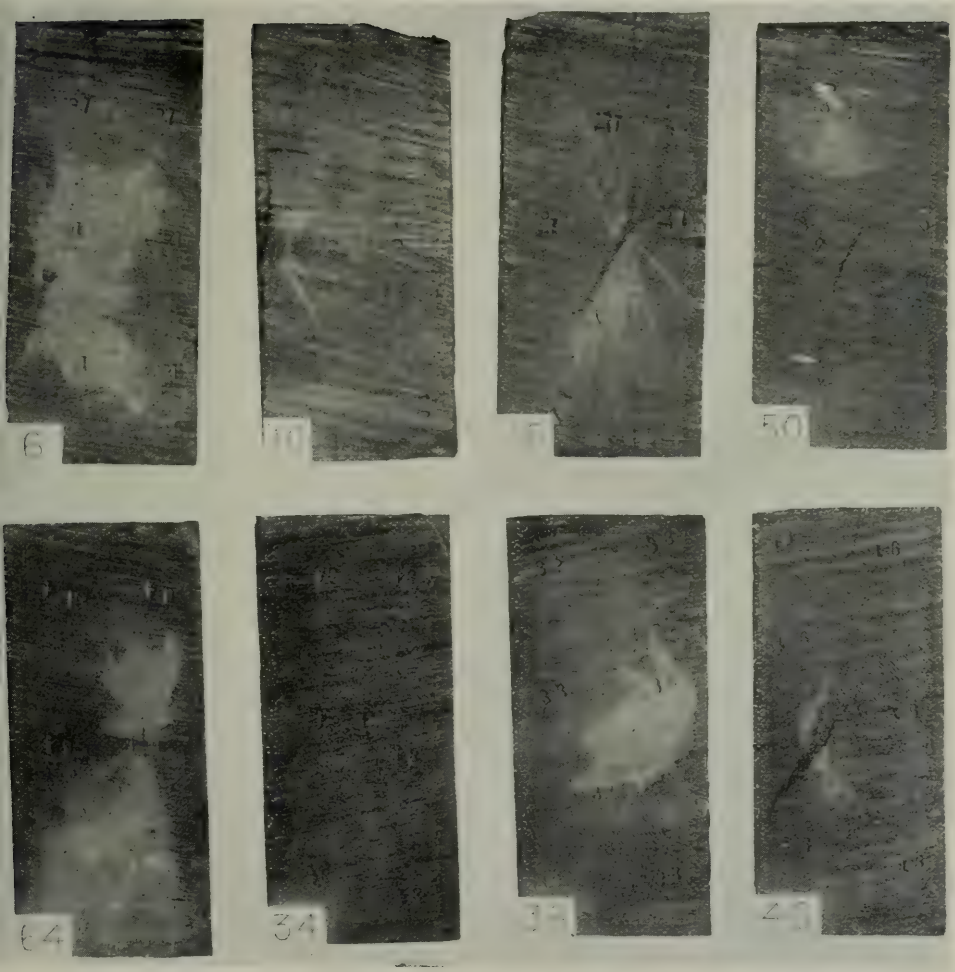
FAILURE OF TREATED SPECIMEN IN COMPRESSION PERPENDICULAR TO THE GRAIN TEST. SPECIMENS WERE TESTED IN JANUARY, 1912, ONE YEAR AFTER TREATMENT.



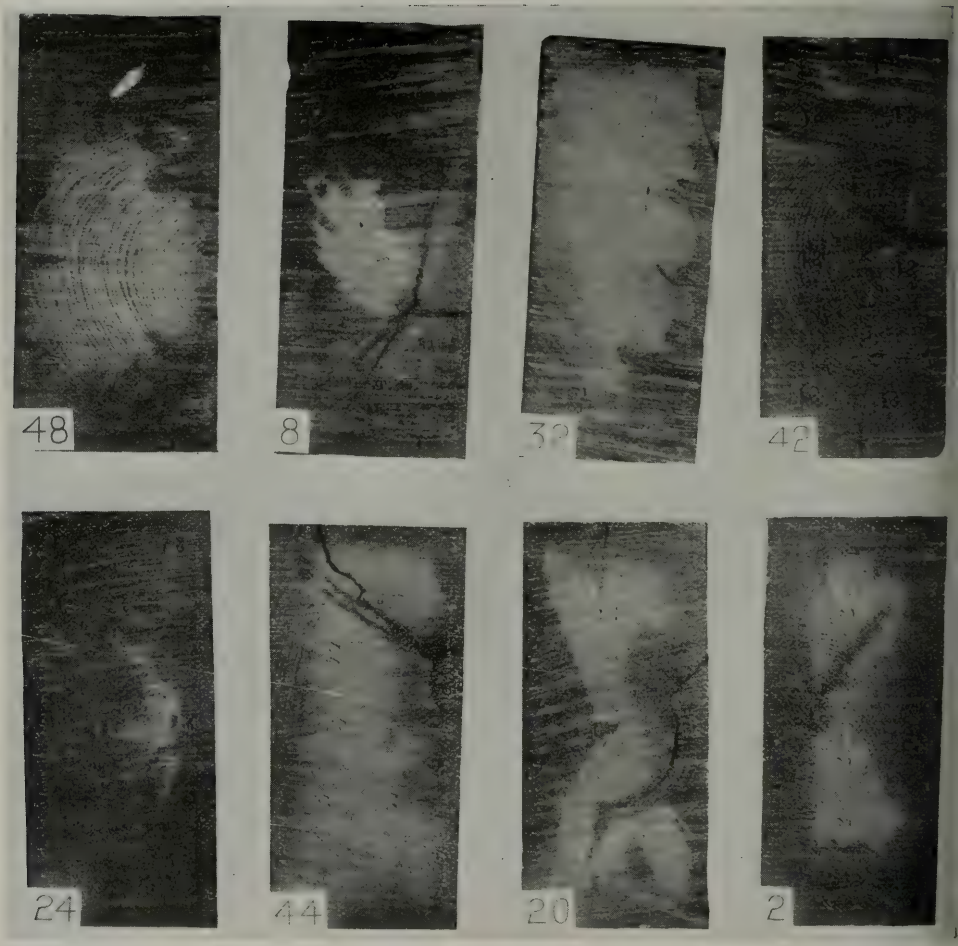
CROSS-SECTION AT CENTER OF TREATED SPECIMENS SHOWING PENETRATION OF CREOSOTE IMMEDIATELY AFTER TREATMENT.



CROSS-SECTION AT CENTER OF TREATED STRINGERS SHOWING PENETRATION IMMEDIATELY AFTER TREATMENT.



CROSS-SECTION AT CENTER OF TREATED STRINGERS SHOWING PENETRATION ONE YEAR AFTER TREATMENT.



CROSS-SECTION AT CENTER OF TREATED STRINGERS SHOWING PENETRATION ONE YEAR AFTER TREATMENT.

PENETRATION OF CREOSOTE.

The penetration of creosote at the center section of each beam tested is shown by photographs on pp. 175 to 178, inclusive. The variation in the amount of penetration in these specimens is very noticeable. An explanation for this variation may be found by referring to the general data sheets on pp. 162 and 163.

The factors most influential in the depth of the penetration are as follows:

(1) Per cent. of moisture.
(2) Per cent. of sapwood.
(3) Number of rings.
(4) Weight per cubic foot.
(5) Amount of pitch in timber.

Factors (3) and (4) give a relative idea of the density of wood. The relation of these various factors is best shown by analyzing individual specimens.

The following specimens were tested immediately after treatment:

SPECIMEN NO. 26.

Creosote, lbs. per cu. ft.....11.5
Weight before treatment, lbs. per cu. ft.....46 5
Rings per inch..... 19
Moisture, per cent.....15.1
Sapwood, per cent.....None

The photograph of this specimen, p. 176, shows a very slight penetration of the creosote.

SPECIMEN NO. 54.

Creosote, lbs. per cu. ft.....10.7
Weight before treatment, lbs. per cu. ft.....37.8
Rings per inch..... 20
Moisture, per cent.....13.7
Sapwood, per cent..... 1.0

This specimen shows the least penetration of creosote of any of those tested.

SPECIMEN NO. 12.

Creosote, lbs. per cu. ft.....11.5
Weight before treatment, lbs. per cu. ft.....39 1
Rings per inch..... 17
Moisture, per cent..... 17
Sapwood, per cent..... 20

This specimen is a very good illustration of the effect of the creosote on sapwood. It may be noticed from the photograph on p. 176 that the sapwood was completely penetrated by the creosote, while the heartwood below was not fully penetrated.

SPECIMEN NO. 4.

Creosote, lbs. per cu. ft.....11.2
Weight before treatment, lbs. per cu. ft..... 38
Rings per inch..... 12
Moisture, per cent..... 36
Sapwood, per cent.....None

In this specimen the creosote reached the heart along checks, but in other parts of specimen the penetration was poor.

SPECIMEN NO. 58.

Creosote, lbs. per cu. ft.	18
Weight before treatment, lbs. per cu. ft.	39.3
Rings per inch	14
Moisture, per cent	55
Sapwood, per cent	None

This specimen shows very complete penetration of creosote, though its moisture content was very high.

SPECIMEN NO. 18.

Creosote, lbs. per cu. ft.	21.3
Weight before treatment, lbs. per cu. ft.	40.5
Rings per inch	10
Moisture, per cent	20.4
Sapwood, per cent	None

This piece shows a fairly perfect penetration.

SPECIMEN NO. 28.

Creosote, lbs. per cu. ft.	13.3
Weight before treatment, lbs. per cu. ft.	44.5
Rings per inch	8
Moisture, per cent	16.75
Sapwood, per cent	8

This specimen shows a fairly good, though irregular, penetration.

SPECIMEN NO. 30.

Creosote, lbs. per cu. ft.	19.2
Weight before treatment, lbs. per cu. ft.	41.3
Rings per inch	8
Moisture, per cent	13.5
Sapwood, per cent	15

Penetration of this specimen was very complete, especially in the sapwood.

The following specimens were tested one year after treatment:

SPECIMEN NO. 32.

Creosote, lbs. per cu. ft.	7.0
Weight before treatment, lbs. per cu. ft.	51.3
Loss of creosote and moisture by one year's weathering, lbs. per cu. ft.	1.5
Moisture, per cent	16.4
Rings per inch	14
Sapwood, per cent	5

This specimen was full of resin and showed very little penetration.

SPECIMEN NO. 44.

Creosote, lbs. per cu. ft.	7.1
Weight before treatment, lbs. per cu. ft.	49.2
Loss of creosote and moisture by one year's weathering, lbs. per cu. ft.	1.7
Moisture, per cent	18.3
Rings per inch	17
Sapwood, per cent	12

This specimen showed the creosote to follow along the checks and heart shake, but did not penetrate deeply into the wood, due to resin in winter growth.

SPECIMEN NO. 48.

Creosote, lbs. per cu. ft.	13.8
Weight before treatment, lbs. per cu. ft.	41.6
Loss of creosote and moisture by one year's weathering, lbs. per cu. ft.	8.6
Moisture, per cent.	6.2
Rings per inch	10
Sapwood, per cent.	None

Specimen was penetrated by creosote to about one-half the area of cross-section. Had no sapwood, but winter rings were full of resin. Center of heart was not in stick so creosote could follow up summer rings better.

SPECIMEN NO. 34.

Creosote, lbs. per cu. ft.	19.1
Weight before treatment, lbs. per cu. ft.	45.5
Loss of creosote and moisture by one year's weathering, lbs. per cu. ft.	2.8
Moisture, per cent.	19.3
Rings per inch	15
Sapwood, per cent.	10

Specimen was thoroughly penetrated by creosote and it had no resin in the winter wood.

SPECIMEN NO. 42.

Creosote, lbs. per cu. ft.	16.4
Weight before treatment, lbs. per cu. ft.	38.7
Loss of creosote and moisture by one year's weathering, lbs. per cu. ft.	6.3
Moisture, per cent.	35.6
Rings per inch	6
Sapwood, per cent.	5

Specimen was thoroughly penetrated with creosote. The center of heart was near the side of stick so creosote had a chance to follow up all summer wood growths.

SPECIMEN NO. 20.

Creosote, lbs. per cu. ft.	8.9
Weight before treatment, lbs. per cu. ft.	49.6
Loss of creosote and moisture by one year's weathering, lbs. per cu. ft.	6.4
Moisture, per cent.	8.5
Rings per inch	21
Sapwood, per cent.	3

The creosote penetrated along shakes and checks on one side, and on the other side by following medullary rays to the center of heart. The stick had resin in some parts and none in others.

The general summary of these specimens shows that the most important factors which influence the penetration of creosote are the density of the wood, as indicated by the number of growth rings per inch, and the presence of pitch in the winter growth rings. The specimens having a small number of growth rings show better penetration than the ones having a greater number of growth rings per inch.

If the specimens contain much pitch in the winter growth, the penetration is very poor. Specimens 32, 44 and 20 show this condition well. These three specimens have approximately the same amount of penetration, but the ring growths vary widely.

A greater per cent. of moisture seems to add rather than detract from the penetration of the creosote, as is shown by the specimens containing the greatest amounts of moisture, viz., specimens 42 and 58. These specimens also show the absence of pitch from their growth rings.

In all specimens the creosote penetrated the sapwood thoroughly, and no specimens which had a high per cent. of sapwood show a low creosote absorption in the sapwood.

MODULUS OF RUPTURE.

The moduli of rupture found in the transverse tests were quite uniform; in fact, much more so than are generally found in timber tests, due, undoubtedly, to the good grade of timber which was used. The average value of 4,955. lbs. per sq. in. is considerably lower for long-leaf pine than that given in many text books; in fact, some authors give this strength for long-leaf pine as high as 13,000 lbs. per sq. in. The most recent tests have proven that these values are too high and, in fact, 5,000 lbs. per sq. in. is a very good average of the transverse breaking strength of such timber. This lower value is due, somewhat, to the fact that most timbers of this size fail by horizontal shear in the transverse test; thus the actual breaking tensile strength is not reached.

Defects in the timber seem to have a much greater effect on the tensile and shearing strength than on the compressive strength. During the whole series of tests none of the beams failed in compression, and only fifteen out of the total failed in tension, the remainder failing by horizontal shear.

The results would seem to demonstrate that stringers might be made shallower. Reducing the depth of stringers would, undoubtedly, be poor practice for bridge work, as additional depth gives added stiffness. It is necessary to allow a larger factor of safety in tension than in shear, since, as the tests show, defects such as knots and cross-grain cause a very large reduction in the transverse strength.

SPECIAL TESTS.

The tests of specimens 13, 14, 39 and 40, the results of which are shown on page 164, indicate that the butt end of a tree is stronger in all respects than the top end. In one case the modulus of rupture was 30 per cent. greater and in the other case it was 24 per cent. greater for the butt than for the top end. A careful examination of the data shows that this large difference is due, mainly, to the presence of knots in the top end. The moduli of elasticity are approximately equal.

In the compression tests the differences are much more marked. Specimen 13 shows poorly in compression parallel to grain test because of a large knot, which is shown in the diagram on page 59. In the compression perpendicular to the grain test there is little difference.

In order to draw definite conclusions regarding the relative strength between the butt and top sections, a number of pieces representative of

the various grades of timber should be tested. The results obtained from the four pieces tested confirm the theory that the butt timber is better for a stringer than the top timber.

EFFECT OF CREOSOTING—IMMEDIATELY AFTER TREATMENT.

The results obtained in this test show that there is very little difference in the strength of the treated and untreated timber. Some of the creosoted specimens, such as No. 12, show a greater modulus of rupture than the untreated half of the same timber. By referring back to the curve and data sheets, causes for the differences in these individual cases may be found. For example, specimen No. 11 had a series of knots along its neutral axis and a large shake with a 20 per cent. of sapwood. In drawing fair conclusions, the averages of a number of tests must be used; such averages are shown on page 162. The average modulus of rupture for untreated specimens is five per cent. greater than that for treated. The horizontal shearing strength also shows two per cent. higher for the untreated. The elastic properties are very nearly identical, the difference being so small that no discussion of this is necessary.

The per cent. of moisture seems to have a considerable bearing on the strength of the timber. Most of the pieces treated were quite dry, averaging about 20 per cent. moisture. No. 57, with the largest per per cent. of moisture, namely 55 per cent., had a modulus of rupture of 4,670 lbs. per sq. in. No. 29, containing only 13½ per cent. of moisture, had a modulus of rupture of 6,160 lbs. per sq. in.

Only 15 out of the 64 specimens failed in tension, the remainder failing by horizontal shear. The presence of season checks and heart shakes seems to be the main factor in influencing the horizontal shear failures. A number of knots near the neutral axis, on the contrary, seems to prevent horizontal shearing.

In the compression parallel to the grain test, the superiority of the untreated specimens is more marked. The elastic limit is 10 per cent. greater, the modulus of elasticity is 9 per cent. greater, and the maximum load is 9 per cent. greater in the untreated than in the treated specimens.

In the compression perpendicular to the grain test, the untreated specimens also show somewhat better than the treated, though the difference is only 2 or 3 per cent. No conclusions should be drawn from this statement since the physical properties referred to are approximated from the curves.

EFFECT OF CREOSOTING—ONE YEAR AFTER TREATMENT.

The average amount of creosote injected was 13.7 lbs. per cu. ft. for the timbers which were tested immediately after treatment, and for the specimens which were tested one year after treatment was 13.3 lbs. per cu. ft. The average loss of creosote by weathering was 3.7 lbs per cu. ft.

The results of the timbers tested one year after treatment show in the transverse tests that the strength was greatly increased. In compression parallel to the grain, the average results show an increase of 10 per cent. In compression perpendicular to the grain the elastic limit shows less, but otherwise an increase in strength is shown.

The following tables show the average strengths of the treated timbers when tested immediately after treatment and when tested one year after treatment, as compared with that of untreated timbers:

TRANSVERSE TESTS.

Specimen.	Elastic Limit Lbs. per Sq. In.	Modulus Rupture Lbs. per Sq. In.	Modulus of Elasticity Lbs. per Sq. In.	Deflection at Failure Inches.	Maximum Horizontal Shear Lbs. per Sq. In.
January, 1911.					
Untreated	4,260	5,160	1,595,000	1.15	415
Treated	4,240	4,980	1,600,000	1.12	408
January, 1912.					
Untreated	3,850	4,750	1,554,300	1.18	377
Treated	4,305	5,263	1,544,700	1.17	414

COMPRESSION PARALLEL TO GRAIN TESTS.

Specimen.	Elastic Limit Lbs. per Sq. In.	Modulus of Elasticity Lbs. per Sq. In.	Maximum Load Lbs. per Sq. In.	Deflection for 2,000 Lbs. per Sq. In.
January, 1911.				
Untreated	5,277	621,000	6,180	0.055
Treated	4,770	568,000	5,650	0.052
January, 1912.				
Untreated	5,075	529,400	5,958	0.051
Treated	5,553	633,000	6,440	0.041

COMPRESSION PERPENDICULAR TO GRAIN TESTS.

Specimen.	Elastic Limit Lbs. per Sq. In.	Load in Lbs. per Sq. In. for a Deflection of 1/10 inch.	3/16 inch.	3/8 inch.
January, 1911.				
Untreated	1,031	727	1,120	1,530
Treated	1,150	711	1,107	1,540
January, 1912.				
Untreated	986	704	1,052	1,483
Treated	945	1,056	1,340	1,691

CONCLUSIONS.

The above data show conclusively that long-leaf pine timber which has been subjected to the full-cell process of creosoting and allowed to weather for a year is in no way inferior to untreated timber. When tested immediately after treatment, the results show the treated timber to be slightly inferior to the untreated timber.

BRIDGES OVER NAVIGABLE RIVERS—SOME PRACTICAL CONSIDERATIONS.

By C. E. Smith,
Bridge Engineer, Missouri Pacific Railway.

The Missouri Pacific Railway crosses a number of navigable rivers in Missouri, Kansas, Illinois, Arkansas, Oklahoma and Louisiana, and maintains 30 movable bridges. The spans vary in length from a 36-ft. deck-plate girder bascule bridge to a swing span 440 ft. in length.

The amount of navigation varies with the locality and with the season of the year. Some of the bridges have never been opened for boats since their construction; some are opened only a few times each year, while others are opened once and sometimes more each day during favorable stages of water and not at all for months during low water periods. On most of these rivers the navigation is notable by its absence, and in no case is there sufficient to afford any comparison between the tonnage passing through a bridge by boat and that passing over the bridge by rail; the latter is always many times, and frequently thousands of times, as great as the former. Notwithstanding the preponderance of rail traffic, however, the boat traffic gets the preference, and where there is necessity of delaying either a train or a boat the Federal Government has ruled that the boat must be given the preference, even though that might mean the stopping of the train.

To illustrate: A few months ago a boat approached one of the bridges a few minutes before the schedule time of a fast mail train, which had been reported to the drawtender as being on time. The drawtender realized that he might not be able to open the bridge, pass the boat and close the bridge without delaying the mail train, so he waited until after the train had passed before opening the draw. The boat suffered a total delay of about 10 minutes; complaint was lodged with the Federal Attorney, who took the matter up with the Legal Department of the Railway Company. Upon presentation of the facts to him, he ruled that the only condition under which it would be permissible to hold a boat to permit a train to cross would arise when the train was so close to the bridge that it could not be stopped before crossing. This information was conveyed to all the drawtenders through the local officials and they are held to strict compliance with the orders.

This preference for boat traffic over rail traffic may appear arbitrary at first glance until it is realized that the navigable waterway is the work of the Almighty—somewhat assisted by Uncle Sam—and is the property of the Common People, while the railroad is the work of mere man and is the property of a soulless corporation.

The rights of the Common People in this regard are thoroughly safeguarded by Federal enactments, copies of the most important of which are given in the Appendix, pp. 258-264.

The most important of these laws with reference to movable bridges is the Act of March 23, 1906, sometimes referred to as the General Bridge Act. It provides in brief that no bridge shall be constructed over any navigable waters until after it has been authorized by Congress, and that construction shall not be commenced until maps of the location and plans and specifications have been approved by the Secretary of War and Chief of Engineers; that such a bridge shall be known as a post route and the United States shall have the right without charge to construct and maintain telegraph and telephone lines across the bridge; that equal privileges shall be granted to all telegraph and telephone companies; that all railroad companies shall be entitled to equal rights over the bridge upon payment of a reasonable compensation, the Secretary of War being the judge as to the reasonableness; that the bridge shall not unreasonably obstruct free navigation; that if any bridge unreasonably obstruct the navigation either on account of insufficient height, width of span, or by difficulty in passing through the opening, the Secretary of War shall specify the changes desired and the time within which they must be made; that such lights and signals be maintained as shall be specified by the Secretary of Commerce and Labor; that the draw shall be opened promptly upon reasonable signal; that in the case of a toll bridge the Secretary of War shall specify the rates; that failure to comply with any order of the Secretary of War or the Chief of Engineers be punishable by a fine not exceeding $5,000, each month to constitute a separate offense, and that the Secretary of War and Chief of Engineers may cause the removal of the bridge at the expense of the owner; that when Congress does not specify a definite time, construction must commence within one year and be completed within three years after the date of authority.

The manner in which the various kinds of movable bridges, piers as well as spans, must be lighted, is set forth in great detail, with illustrations, in Bulletin issued by the Department of Commerce and Labor.

The question, "What is a navigable river?" naturally suggests itself. The Federal laws do not afford an answer and there is no competent general ruling in existence, nor does it seem possible that there can be given a satisfactory definition. Particular streams or parts of streams have been and may be declared navigable by Acts of Congress, by rulings of the War Department or by courts of competent jurisdiction.

Definition given by a Federal Attorney is, in part, as follows:

"A navigable stream is one that can be navigated by power boats."

Definition given by an Engineer Officer is as follows:

"A navigable stream is one which in a state of nature does or is capable of carrying commerce in the manner in which commerce is usually carried."

After a search of several years the writer has concluded that the following general definition is as good as any:

"A navigable river is one that has been declared navigable by competent authority or that is, in fact, navigable at any time by any boat or raft."

In applying this definition to any particular case the rule of reason must be applied.

In addition to the general laws governing movable bridges over navigable rivers, the War Department issues rules and regulations to govern the opening of bridges, the rules and regulations varying as may be necessary to meet local conditions. The following, relating to a number of tributaries of the Mississippi River and their tributaries in the Southwestern States, are quoted as an example:

RULES AND REGULATIONS TO GOVERN THE OPENING OF DRAWBRIDGES OVER THE ARKANSAS RIVER, BLACK RIVER, CACHE RIVER, LITTLE RIVER (A TRIBUTARY OF ST. FRANCIS RIVER), LITTLE RED RIVER, ST. FRANCIS RIVER AND WHITE RIVER IN THE STATES OF ARKANSAS AND MISSOURI.

"In pursuance of the authority conferred by Section 5 of the River and Harbor Act of August 18, 1894, the following regulations are prescribed to govern the opening of drawbridges over the following named rivers in the States of Arkansas and Missouri: Arkansas River, Black River, Cache River, Little River (a tributary of St. Francis River), Little Red River, St. Francis River and White River.

"1. Whenever a steamboat or other water craft approaches a drawbridge and desires to pass through the draw thereof, the officer or person in charge of said steamboat or other water craft, when at least one-half mile distant from the bridge, shall cause signal to be sounded as follows:

"(a) If ascending the river, one long distinct blast of a steam whistle, an air whistle, or a horn.

"(b) If descending the river, three long distinct blasts of a steam whistle, an air whistle, or a horn.

"2. When any water craft is to leave a landing not one-half mile distant from a bridge, with the intention to pass through that bridge, the officer or person in charge of such craft shall cause the prescribed signals to be given a sufficient time before leaving the landing to allow the bridge to be opened at its ordinary operating speed.

"3. Upon hearing the signals prescribed, the tenders or operators of the drawbridge shall at once open the drawspan of the bridge for the prompt passage of said steamboat or other water craft: *Provided,* that the drawbridge may not be opened when there is a train, wagon, or vehicle at the time passing over said drawspan, or a train approaching so closely that it cannot be safely stopped before reaching the bridge, but it shall be opened as soon as the drawspan may be cleared: *Provided further,* that wagons, vehicles and trains shall not be stopped on said drawbridge, or on the drawspan, for the purpose of delaying the operation of the drawspan, nor shall steamboats or other water craft be so manipulated as to hinder or delay the operation of the drawspan, but all passage, through, or under the said drawbridge shall be prompt to prevent delay to either land or water traffic.

"ROBERT SHAW OLIVER,
"Acting Secretary of War."

War Department, April 4, 1907.

In 1905, after regulations governing the operation of drawbridges over the Arkansas River had been received, the Railway Company asked

for rules and regulations governing other navigable rivers crossed by . and received the following from the United States Engineer:

"I have your letter of the 28th inst., asking for copies of rules and regulations governing operation of drawbridges on your lines at Judsonia, Paroquet, New Augusta, Fulton and Parkin. Fulton Bridge is not in my district, it being in the Vicksburg district. No special regulations, similar to those issued for the Arkansas River bridges, have been issued for the other bridges mentioned in your letter. So many complaints were received about delayed navigation on the Arkansas River, that the special regulations were issued for that stream, so that it would be easier to reach the railways through the courts. So long as no complaints of delayed navigation are received regarding bridges over White, Black, Little Red and St. Francis rivers, it is not likely that special regulations will be issued."

All rivers that are designated as navigable rivers are not navigable in fact, nor does the War Department require the construction of movable bridges over all so-called navigable rivers. A notable example of this is the Kaw River, which joins the Missouri River at Kansas City, Kan. The Kaw River has been declared a navigable river, the Government has established harbor lines for quite a distance above its mouth and has ordered the reconstruction of a large number of bridges to provide increased height, width and depth of foundations, the latter to do away with the necessity for protecting former piers with riprap. In a distance of five miles above its mouth the Kaw is crossed by 15 bridges, none of which have movable spans. With a few exceptions, the underclearance of the steelwork, after the reconstruction of the low bridges, will be only a few feet above high water level, effectually preventing navigation at high water which would otherwise be prevented by the swift current. At extreme low water the clearance under the bridges is about 30 ft. and the depth of water hardly sufficient to float a small barge. An occasional sand barge uses the river at occasional favorable stages and that constitutes the navigation. The jurisdiction of the War Department over the river is absolute, however, and the reconstruction of bridges now under way to comply with Government requirements will cost several millions of dollars. The example is cited here simply to call attention to the reasonableness of the United States Engineers in not demanding movable bridges to accommodate a small amount of navigation. In fact the result of the writer's negotiations with them indicates the uniform reasonableness of the Engineer Officers in their interpretation of the laws and rules relating to navigable rivers.

Although theoretically it is the duty of the Railway Company to maintain watchmen and turning machinery at each of its movable bridges and to be always ready to open a bridge at a moment's notice, it is practically unnecessary to bear such expense continuously at bridges that are seldom or never opened. At such points it is customary to lay the rail continuous over the bridge, to set the end wedges (in a swing bridge) so that the draw will not tip under traffic, and to dispense with watchmen. When such bridges must be opened it is customary for the boat owner

FIG. 1.

MAP SHOWING PRINCIPAL NAVIGABLE RIVERS OF THE UNITED STATES.

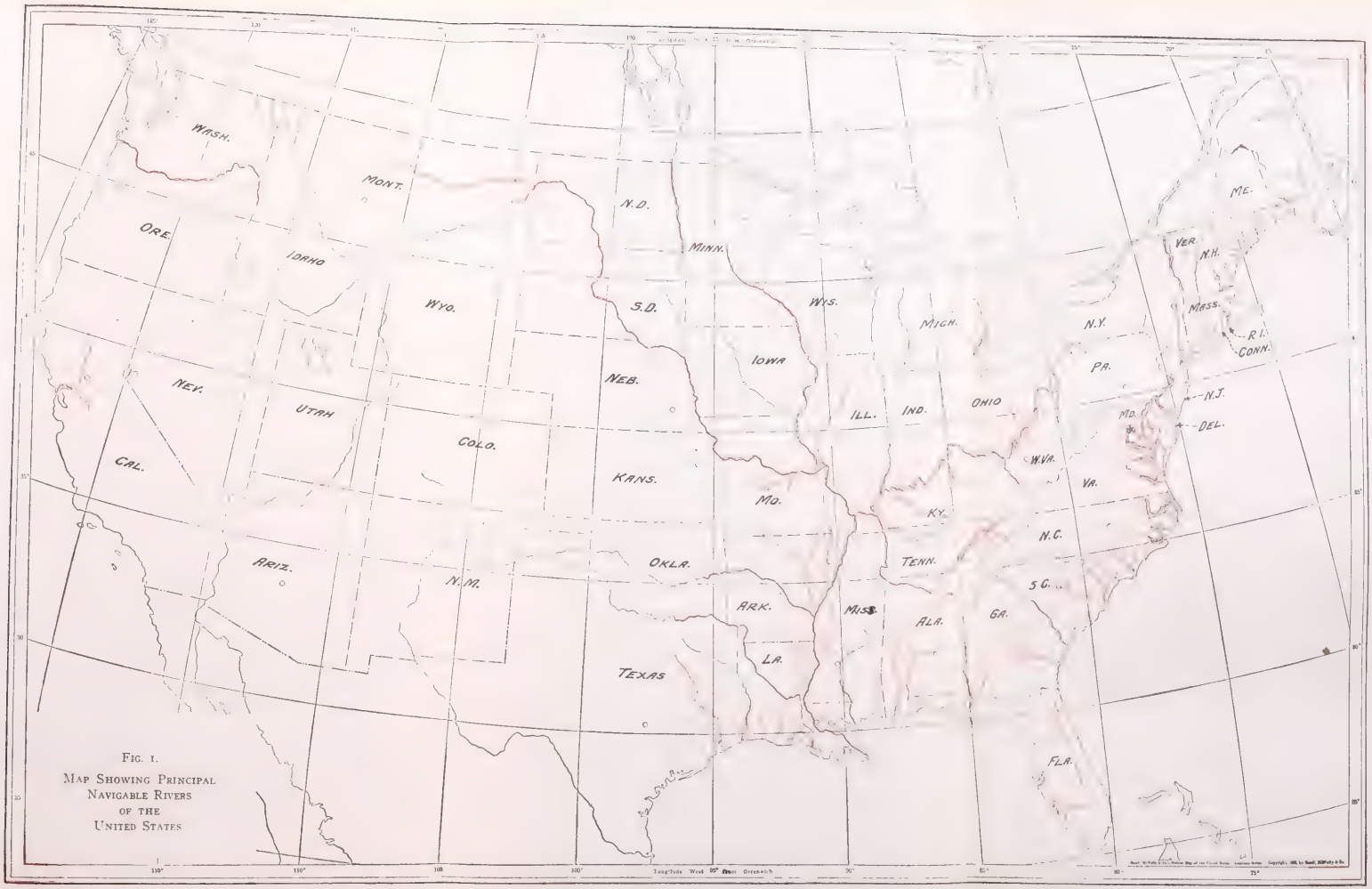


FIG. 1.

MAP SHOWING PRINCIPAL
NAVIGABLE RIVERS
OF THE
UNITED STATES

or Master to notify the section gang or nearest local Agent, who arrange to open the bridge or to secure the necessary help. The relations between the Railway Company and the boatmen at such places have invariably been harmonious, as such relations usually promote the interests of both parties.

Occasionally, however, a boat owner approaches a drawbridge over such a stream with the apparent expectation that the railway employes are standing on their toes to serve him, even though his may be the first boat at that point in years and his arrival unexpected. He is one of the Common People, surveying and using his inalienable property, the navigable river, which he finds so unreasonably obstructed by the Railway Company's bridge. His presence in our midst, as it were, is usually first discovered by the section gang or by a crew on a passing train, in which latter case the sectionmen are sent to investigate. The opening of the bridge soon follows. In such cases there is usually a claim for damages, actual and punitive, and plenty, for the delay to the boat, and the Railway Company settles outside of court if the boat owner can be prevailed upon to see his loss, if any, in a reasonable light. An unreasonably large claim for one day's delay at a bridge that had not been opened previously for six years is now being adjusted.

Another fruitful source of complaint is the presence of stubs of old falsework piling in the channel. These are sometimes left in by the contractor cutting the piles off at extreme low water, assuming that boats cannot use the river until the water is deep enough over the pile stubs to float the boats, or by breaking the piles off, presumably at the bottom of the river but frequently higher, or they are the remaining stubs of piles that may have been swept away by flood and driftwood, or portions of some former bridge. Whatever may be the reason for their presence, it is practically certain that sooner or later a boat will hit them and they will result in delay or damage or both, with resulting claims. It is the practice of the writer in all cases to insist on the pulling of all falsework piles and former pile piers that stand in navigable channels and this requirement is clearly set forth in the specifications and carefully watched.

It occasionally happens that navigation develops in a stream over which a bridge with simple spans has been maintained for many years. In many cases such bridges must be reconstructed as movable bridges, but in others the necessity for permitting boats to pass occurs so seldom that when the design of the bridge permits, the most economical solution is the occasional temporary raising or removal of a span by means of a derrick car. There are many bridges that have been opened in this manner for years.

At bridges that are seldom opened, but where watchmen are maintained, it is difficult to maintain discipline on account of the monotony. The watchmen frequently leave the bridge between trains for shooting or fishing trips, with consequent delays to boats and subsequent complaints.

It is also, under the law, clearly the duty of the Railway Company to maintain channels under movable spans or to maintain movable spans over channels. It frequently happens, after a movable bridge has been constructed over the then channel, especially in a stream subject to quick rise, swift flow and shifting of sandy bottom, that the former channel under the movable span will fill up and a new channel be formed under one of the fixed approach spans. When this takes place it becomes a very nice problem to determine what course to pursue.

In the construction of the Illinois Central Railroad bridge over the Missouri River near Omaha, Neb., the channel moved out from under the original draw span while it was under construction. The Company immediately arranged for the construction of a second draw span, duplicate of the first, to span the remainder of the river, so there are now four draw openings.

For a somewhat similar reason the bridge of the St. Louis Southwestern Railway over the Arkansas River, near Pine Bluff, Ark., has two draw spans, as shown in the illustration.

The problem of maintaining a movable span over the channel has been simplified by the recent development of the vertical lift bridge. With this type of bridge it is practicable to cross a river with a number of simple spans of equal length on ordinary piers. The towers, counterweights and lifting mechanism are first applied to the span over the channel; at any later date the lifting apparatus may be moved to lift any other span under which the channel may be and the cost of the change will be only nominal as compared to the cost of changing any other type of movable bridge for a similar purpose. A bridge designed with this idea has recently been completed across the Arkansas River between Fort Smith and Van Buren, Ark. There are nine spans 196 ft. in length, the lift bridge being of the Waddell and Harrington type.

In the construction of a new bridge or the reconstruction of an old bridge over a navigable river one of the first and frequently the most important step is the negotiation with the United States Government. The negotiation is governed by the following rules:

RULES TO BE OBSERVED BY PARTIES MAKING APPLICATIONS, UNDER THE PROVISIONS OF SECTION 9 OF THE ACT OF CONGRESS APPROVED MARCH 3, 1899, FOR APPROVAL BY THE SECRETARY OF WAR OF PLANS FOR A BRIDGE.

"When application is made pursuant to the provisions of Section 9 of the Act of Congress approved March 3, 1899, for the approval by the Secretary of War of plans for a bridge, the applicant will be required to furnish—

"1. A copy of, or reference to, the law of the State authorizing the construction of the bridge, certified to by the Secretary of State, under seal.

"(a) If the bridge is to be built under authority of a special act of a State legislature, a copy of such act duly authenticated should be furnished.

FIG. 2—ILLINOIS CENTRAL DRAWBRIDGE OVER MISSOURI RIVER, NEAR OMAHA, NEB.

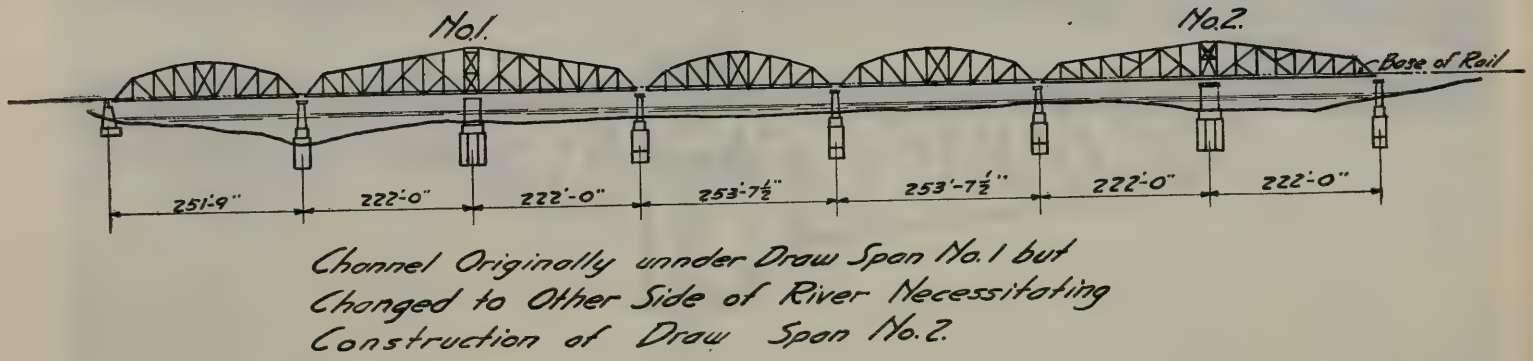


FIG. 3—ST. LOUIS SOUTHWESTERN RAILWAY, ARKANSAS RIVER BRIDGE, NEAR PINE BLUFF, ARK.

FIG. 4—VERTICAL LIFT BRIDGE OVER ARKANSAS RIVER, BETWEEN VAN BUREN AND FORT SMITH, ARK.

"(b) If a bridge is to be built under authority of a general law, a simple reference to such law by volume, page and section will be sufficient.

"(c) Where the legal authority to build a bridge is shown conclusively by the charter or articles of incorporation of a company, a copy of such paper, *infra,* will be sufficient.

"(d) In cases where State laws vest the power to authorize the construction of bridges in county officers, such as boards of supervisors or county courts, certified extracts from the proceedings of such organizations must be furnished.

"2. Drawings, in triplicate, showing the plan of the bridge, that is, length and height of spans, width of draw openings, position of piers, abutments, etc., and those features which affect navigation. (Details of construction are not required.)

"3. A map, in triplicate, showing the location of the bridge, giving, for the distance of one mile above and one-half mile below the proposed location, such data in regard to low and high water, direction and strength of currents, soundings, existing bridges, etc., as may be necessary to enable the Secretary of War to judge whether the location is a proper one.

"If the applicant is a corporation, in addition to the papers enumerated above, there will be required—

"1. A copy of the charter or articles of incorporation of the company, certified to by the Secretary of State, or such other officer as may have the custody of the original, under seal.

"2. A copy of the Minutes of the organization of the company, certified to by the secretary of the company, under seal.

"3. An extract from the company Minutes showing the present officers of the company, certified to by the secretary thereof, under seal.

"War Department,
"Office Chief of Engineers,
"July 1, 1899,
"62253—08."

In the case of a new bridge where there has not previously been one it is necessary to secure the passage of a special Act of Congress, which, unless the bridge is of unusual magnitude or possesses other unusual features, commonly takes the following form:

AN ACT TO AUTHORIZE THE ST. LOUIS, IRON MOUNTAIN & SOUTHERN RAILWAY COMPANY TO CONSTRUCT AND OPERATE A BRIDGE ACROSS THE ST. FRANCIS RIVER IN THE STATE OF ARKANSAS AND FOR OTHER PURPOSES.

"*Be it Enacted by the Senate and House of Representatives of the United States of America in Congress Assembled,* that the St. Louis, Iron Mountain & Southern Railway Company, a corporation created and existing under and by virtue of the laws of the States of Missouri and Arkansas, is hereby authorized to construct, maintain and operate a bridge across and over the St. Francis River in the State of Arkansas at such point in Section 25, Township 3 North, Range 4 East, in Lee County in said State, suitable to the interests of navigation, as may hereafter be selected by said company for crossing said river with its railway line, in accordance with the provisions of an Act entitled, 'An Act to Regulate the Construction of Bridges Over Navigable Waters,' approved March 23, 1906.

"Section 2. That the right to alter, amend or repeal this Act is hereby expressly reserved.

"Approved August 15, 1911."

This Act of Congress is cited as authority when maps, plans and specifications are submitted to the United States Engineer Officer for approval.

In the case of reconstruction it is necessary to look up the authority under which the original bridge at the location was built. This is sometimes in the form of a very general power conferred by the State, in the charter of the railway, or by a special statute, or in the form of a special Act of Congress. When the navigable portion of a river lies wholly within one State the authority of the State is recognized by the Federal Government and the United States Engineer Officer consents to receive and consider the plans. In other cases the State authority is recognized as sufficient to cover the original construction, but a new special Act of Congress is necessary before plans for reconstruction will be considered or approved.

An Act authorizing the reconstruction of a present bridge usually takes the following form:

"An Act to authorize the construction, maintenance and operation of a bridge across the Black River at Paroquet, Ark.

"*Be it Enacted by the Senate and House of Representatives of the United States of America in Congress Assembled*, that the St. Louis, Iron Mountain & Southern Railway Company, a corporation organized and existing under the laws of the States of Missouri and Arkansas, is hereby authorized to construct, maintain and operate a railroad bridge and approaches thereto across the Black River, at a point suitable to the interests of navigation, at Paroquet, Ark., or to reconstruct, maintain and operate the present bridge of said company across said river in accordance with the provisions of an Act entitled, 'An Act to Regulate the Construction of Bridges over Navigable Waters,' approved March 23, 1906.

"Section 2. That the right to alter, amend or repeal this Act is hereby expressly reserved.

"Approved February 19, 1910."

The rules of the War Department require that when plans and specifications of a proposed bridge are submitted to the Engineer Officer they must be accompanied by a map showing the river lines one mile above and one-half mile below the proposed crossing, together with cross-sections of the river at frequent intervals. The three points that are given the most attention by the War Department are:

(a) Location of crossing.
(b) Location of movable span in the bridge.
(c) Clear width of channel opening.

When the proposed bridge is to replace a former bridge which has been easily passed by boats and in regard to which there have been no complaints from the river interests, the approval of the Engineer Officer is usually merely a matter of form. Where boats have had difficulty in passing through the opening, or where there have been complaints for other reasons, or in the case of a bridge in a new location, the Engineer Officer either corresponds with the interested

parties or holds a public hearing to determine what provision must be made for navigation.

From the standpoint both of the Railway Company and of the War Department it is most desirable that a movable bridge be located in the longest possible straight reach of the river, but there are frequently conditions that impel the Railway Company to choose a crossing at a less desirable location. Where a bridge is located near or at a bend in the river, the boat owners and the War Department usually demand a larger opening than would be demanded in a straight reach. To illustrate: Two drawbridges were constructed over the Black River in Arkansas in 1911. The bridge near the mouth has a draw span 267 ft. long, providing openings 118 ft. wide in the clear, which is ample on account of the straight river, while the other bridge, about 100 miles from the mouth, has a draw span 440 ft. long providing openings about 200 ft. wide in the clear, which is necessary on account of being located in a sharp bend.

The width of opening and location of channel are matters the determination of which frequently takes many conferences and much time.

When the Act of Congress has been passed and the plans are satisfactory to the War Department, the approval of the Secretary of War and of the Chief of Engineers is conveyed in a form somewhat as follows:

"*Whereas,* By an Act of Congress, approved February 19, 1910, entitled, 'An Act to authorize the construction, maintenance and operation of a bridge across the White River, at Augusta, Ark.' (Public—No. 53), the St. Louis, Iron Mountain & Southern Railway Company, a corporation organized and existing under the laws of the States of Missouri and Arkansas, was authorized to construct, maintain and operate a railroad bridge and approaches thereto across the White River, at a point suitable to the interests of navigation, at Augusta, Ark., or to reconstruct, maintain and operate the present bridge of said company across the said river, in accordance with the provisions of the Act of Congress entitled, 'An Act to regulate the construction of bridges over navigable waters,' approved March 23, 1906 (34 Stat. L., 84); whereby it is provided that such bridge shall not be built or commenced until the plans and specifications for its construction, together with such drawings and map of location thereof as may be required for a full understanding of the subject, have been submitted to and approved by the Chief of Engineers and by the Secretary of War;

"*And Whereas,* Said St. Louis, Iron Mountain & Southern Railway Company has submitted for examination and approval plans, specifications, drawings and map of location of a bridge proposed to be reconstructed by it over the said river at said place; which comply with the requirements of said Act of Congress, and have been approved by the Chief of Engineers, United States Army;

"*Now, therefore,* This is to certify that the said plans, including specifications as shown thereon, drawings and map of location, covering the reconstruction of said bridge, which are hereto attached, are hereby approved by the Secretary of War, subject to the following conditions:

"1. That the Engineer Officer of the United States Army, in charge of the district within which the said bridge is to be rebuilt, may super-

vise its reconstruction, in order that said plans, and the requirements and provisions of said Act of Congress applicable thereto, shall be complied with.

"2. That said company shall be liable for any damage that may be inflicted upon navigation interests through delays or interruptions due to reconstruction of the bridge.

"Witness my hand this 15th day of March, 1910.

"(Signed) ROBERT SHAW OLIVER,
"Assistant Secretary of War."

It frequently happens that on account of Congress not being in session or on account of delays caused by routine, it is not possible to get Act of Congress passed as soon as it is desired to start construction. In such a case, if the matter is taken up in the proper manner with the Engineer Officer and the wishes of the War Department are fulfilled, the Secretary of War will express the satisfaction of the Department with the plans and state that no action will be taken by the Department if work be commenced at once, the passage of the Act and formal approval of plans to follow. Such permission to proceed usually takes the following form:

"I beg to inform you that while the War Department is without authority at this time to take any affirmative action toward approving plans for a bridge over this river in the absence of proper legislative authority for its construction, it will consider such plans as the Company may desire to present now and take such action thereon as may be practicable under the circumstances in furtherance of the Company's wishes, but such action would at most be limited to a waiver of interference by the Department with the work, provided the plans make ample provision for the accommodation of navigation at the locality.

"Very respectfully,
"SECRETARY OF WAR."

It will be seen that even during the construction or reconstruction of a bridge the rights of navigation must be respected and it is the duty of the Railway Company to maintain navigation or to pay damages that are incurred by private parties if the channel be obstructed. Each case must be handled on its merits, controlled by local conditions such as actual and relative amounts of rail and boat traffic. In the case of very heavy traffic lines it is preferable, where practicable, to change alinement when such bridges are reconstructed in order to avoid interference with either class of traffic. In congested districts this is frequently impossible and it becomes necessary to reconstruct in the former location under traffic. On light traffic lines interference with trains can be avoided without much increase in cost so that the extra cost of changing the location is seldom warranted and it is most economical to reconstruct in the former location under traffic.

The writer has heard that in the past there were instances of navigable rivers having been declared closed for specified periods by the Chief of Engineers or Secretary of War or by Congress, but it is the invariable practice at the present time to refuse permission to close the channel even for a short period. It might be possible at

the present time to secure the passage of an Act of Congress closing a river to navigation during a specified period for the reconstruction of a bridge, but it would probably be against the recommendation of the War Department and consequently would require more powerful political influence than most railways can command or would care to use for such a purpose if available.

When the War Department is requested to close a navigable channel for a period during reconstruction reply is invariably received somewhat as follows:

"In reply to your letter of the 8th ult., in regard to the reconstruction of your bridge No. 1515 over the Black River near Paroquet, Ark., in which you request permission of the War Department to close the channel, I have been authorized by the Chief of Engineers to inform you that while the Department is without power to authorize the closing of a navigable stream to navigation no objection will be interposed to the proposed work during the period mentioned, it being understood that your Company may be liable for any damage sustained by navigation interests by reason of its operations."

It becomes practically necessary to work out a method of reconstruction that will not obstruct navigation or to pay the damages that are incurred by private interests. The United States Engineer Officer will usually make arrangements, if possible, to keep Government boats away from the bridge, if request be made, for a reasonable period, but this is not always possible. It has been the uniform experience of the writer that the Engineer Officers are ready to make reasonable sacrifices where practicable, to avoid interference with the bridge construction.

It was the practice of many railways in the past (and the practice still obtains on some roads) to compel the Contractor to work out a method of taking care of navigation and to make him responsible for any damages arising out of delays or injuries to boats during construction. This practice was objectionable for several reasons—bidders would not familiarize themselves sufficiently with local conditions to be able to make a close estimate of the probable cost to which they would be put in caring for navigation; consequently a sum based on a guess would be added to the bid. In case the sum was too large the Railway Company would pay for more than it was getting; if too small the Contractor would soon find it out and would make every effort to keep within his estimate, with consequent delays to boats and dissatisfaction among their owners.

It is well to realize that the Railway Company must pay for the delays to navigation or for the means to avoid delays, and that it is better to pay the actual amount in either case than to gamble on it by getting an estimate. It is not difficult to write the specifications covering any specific case in such a manner that the Contractor will not be subjected to a hardship or forced to take an unreasonable profit.

In the Southwest it is practically impossible to predict the amount of navigation that will be carried on during the reconstruction of a bridge. Of course every effort is made to carry out the work during expected periods of low water, but after five years' experience with rivers in the Southwest it appears to the writer that there is no certain period of low water. The rivers are almost certain to be high from November to July and are frequently high from July to November; in fact, during some years there are no well-defined low-water periods. If the river reaches a sufficiently low stage, however, navigation will cease entirely. On the other hand, the uncertainty of the low-water period and the fact that frequently the stage of a river throughout an entire year is sufficient for navigation, make it necessary to provide for navigation during construction.

It is sometimes possible, where a portion of a river is used by only a few boats, to make amicable arrangements with the owners, possibly by the payment of relatively small sums, so that the company will be safe in closing the channel. Such a course, however, is invariably followed by an immediate increase in the number and importance of the boats using the river. Much has been said and written about the decadence of river traffic in the western rivers, and the means that have been employed to increase it. The writer has been forced to the conclusion that there is no method of accomplishing the desired result in stimulating navigation over any portion of a river so effective as the construction or reconstruction of a bridge.

There are many ways of taking care of navigation during construction, each case presenting an entirely different problem, the solution of which depends on local conditions.

On the Missouri Pacific Railway it is the practice to let separate contracts for (a) substructure; (b) fabrication, and (c) erection of each bridge.

It is the invariable practice of the writer to design the substructure of the new bridge in such a manner that, whether it be a new location or renewal, the foundation can be put in and completed without stopping navigation. Provision is then made in the specifications that the Contractor's work must be carried on in such a way as not to interfere with boats and he is held to strict compliance with that provision. Considerable contraction of the channel is usually possible during construction for the reason that the boats are much narrower than the channel, the greater width being required to provide for free passage under all conditions.

The method of erection that will be followed is worked out and described in detail in the specifications. Erection is usually let on a tonnage basis, the price including putting in and taking out the falsework. If any special arrangement of falsework is necessary, such as the installation of a girder span on pile piers, the bidders are requested to name a price for making the special arrangement. Bidders are also

requested to name a unit price for each time the bridge must be opened during erection to permit the passage of a boat. The specifications also provide that during erection the Contractor's work must be carried on in such a manner as not to interfere with boats.

Since the above method of handling has been adopted very little trouble has been experienced in taking care of navigation and few complaints of delays have been received. The detailed methods that were adopted to secure the desired result at several points on the Missouri Pacific Railway, together with short descriptions of the bridges, are given in the following pages. In all the cases the work was carried out under traffic by Contractors and was so handled that no complaints of delays to trains were received from the Transportation Department. Speed of trains was always somewhat restricted across the bridges.

DRAWBRIDGE OVER TENSAS RIVER, NEAR CLAYTON, LOUISIANA.

The former bridge, consisting of one 150-ft. Howe truss through draw span on pile piers and pile trestle approaches 300 ft. long, was replaced on the same center line by a 150-ft. deck plate girder center disc-bearing draw span (hand-operated) and four 75-ft. deck plate girder approach spans on concrete piers and abutments, both old and new bridge being single track. The old bridge had been in place twenty-two (22) years when replaced, and no complaint had ever been received of insufficient width of channel. Practically no change had taken place in the bank lines during that period, as Tensas River is quite a sluggish stream that attains its greatest height from backwater when the Mississippi River is high.

The plan for the new bridge provided for draw openings approximately equal in width to the former openings, and the plan was promptly approved by the War Department. The approach spans were simply for the purpose of replacing an equivalent length of pile trestle in order to reduce the obstruction to the flow of the river and to reduce the cost of maintenance.

The new piers were so located as to not interfere with the old piers and yet to leave sufficient width of temporary channel for the passage of boats, there being no boats of very great width in that neighborhood at the time of the construction of the bridge.

The construction of the foundations presented no unusual difficulties. Open timber crib and wooden sheet pile cofferdams were used: the excavation was made and piles driven before they were pumped out. The concrete for the two bank piers and the two abutments was placed entirely in the dry. The footing courses for the three draw piers were placed under water and the remainder placed in the ordinary manner. The bed of the stream was composed of a very compact mix-

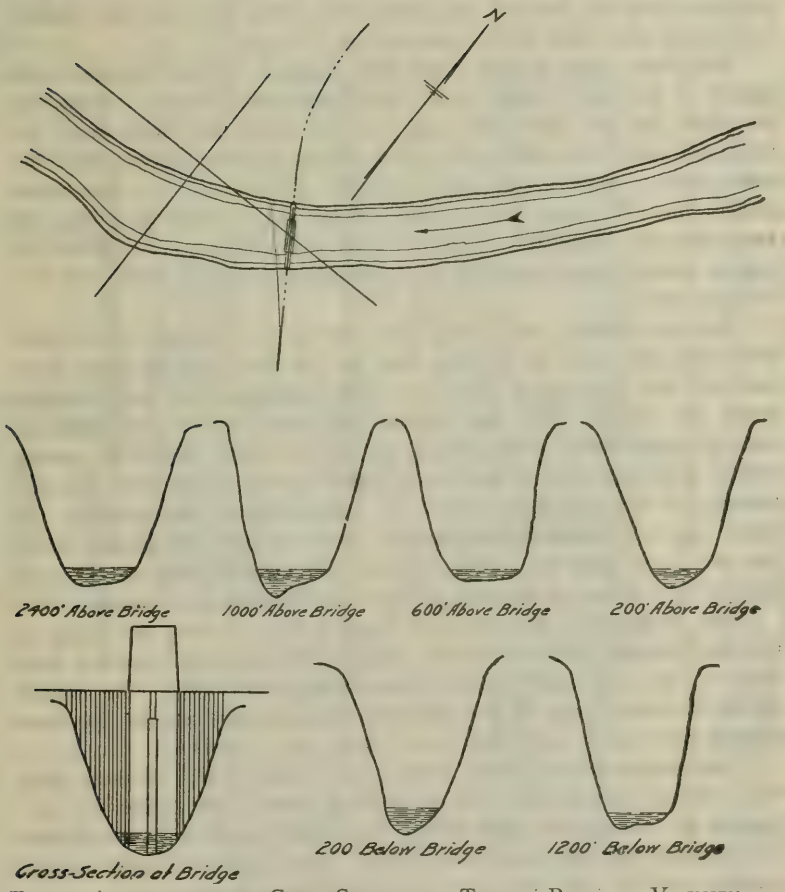


FIG. 5—ALINEMENT AND CROSS-SECTION OF TENSAS RIVER IN VICINITY OF BRIDGE.

ture of sand silt and clay, into which, by very hard driving, the foundation piles were driven 40 ft.

The four approach spans were placed by gallows frames resting on the ends of the piers. The girders on cars were run out under the frames, raised off the cars and the cars pulled out from under. The rails, ties and trestle in the way of the girders were then removed, the girders lowered to place and track connected up.

The draw span girders were each shipped in three pieces to be spliced in the field. Each section was placed in a manner similar to that used for the approach spans, the old pivot pier being used for falsework under the north splice, and falsework being placed under the south splice. During the placing of the sections of the draw span girders the old timber floor system of the Howe truss span was cut away and the trusses left in place. After the girders were in place the trusses were thrown into the river, floated out to the bank and dismantled there.

For the greater part of the time during the erection of the new draw span the water in the river was so low that no large boats could navigate and such small boats as could navigate could pass through under the bridge. For that reason no special effort was made to effect a quick change from the old to the new span. The first turning of the new span was accomplished in about two weeks after the last turning of the old span. Near the completion of the erection the water rose to a point that permitted a boat to reach the bridge before the new draw span was ready to turn. The slight delay to the boat resulted in a claim for damages of $75.00, which was easily settled.

The bridge was designed for Cooper's E-50 loading, according to the specifications of the Missouri Pacific Railway, which conform with those of the American Railway Engineering Association. The weight of the structural steel in the approach spans is 150 tons, in the draw span 86 tons and of machinery in the draw span 13 tons.

The estimated cost of the bridge was $60,000, which is about what the structure should have cost in ordinary times. The work was performed by contract in 1908 during the slack period that immediately followed the financial depression of 1907, when Contractors were eagerly seeking work to keep idle plant and organization busy.

The total actual cost to the Railway Company was about $45,000, but it is the opinion of the writer that had the total cost been somewhere between $50,000 and $60,000 there would certainly have been a slight profit to the Contractors instead of an apparent loss.

The steel was fabricated by the Pennsylvania Steel Company. The foundation work and erection were performed by the A. M. Blodgett Construction Company.

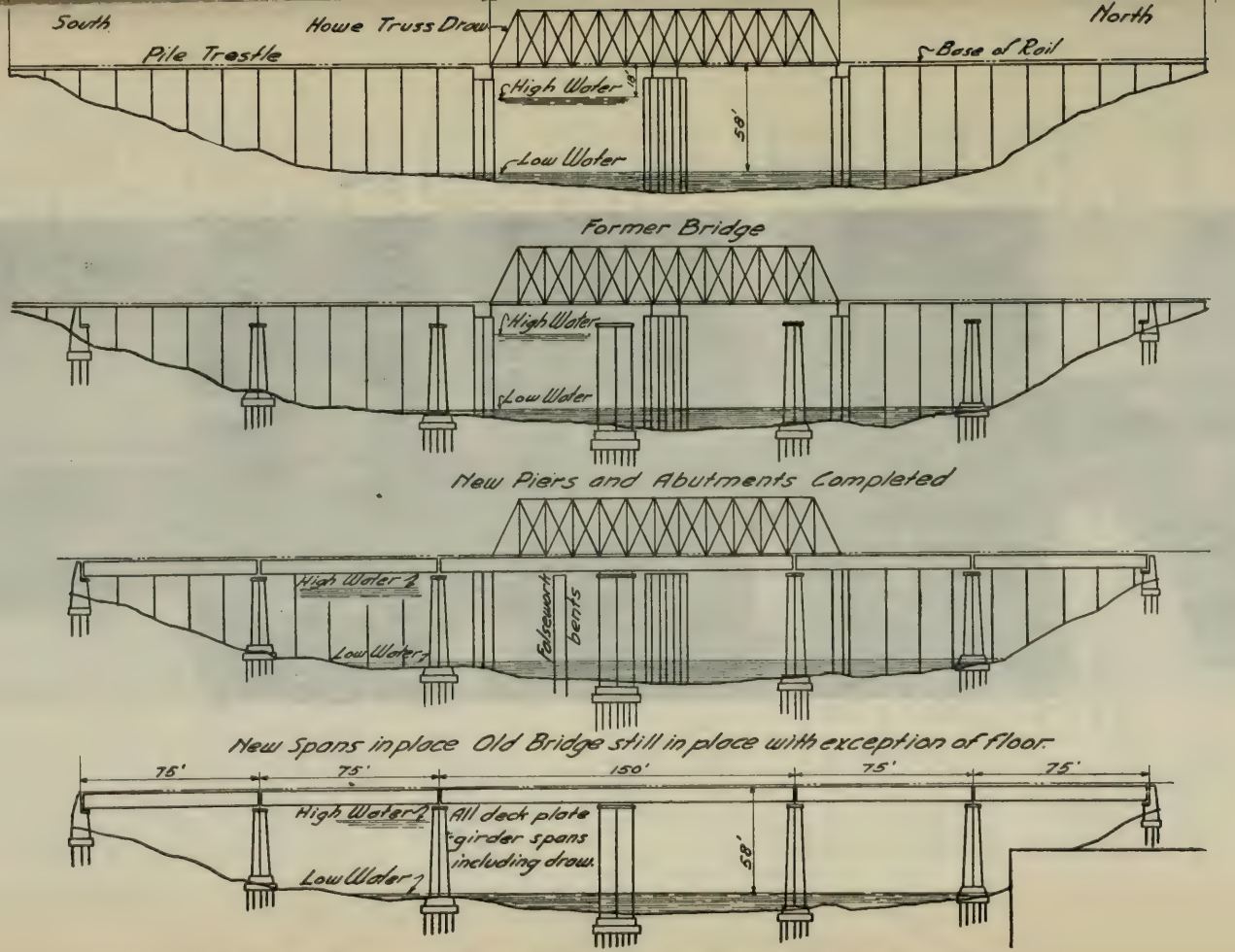


FIG. 6—SIDE ELEVATION OF TENSAS RIVER DRAW AT CLAYTON, LA., IN FOUR STAGES.

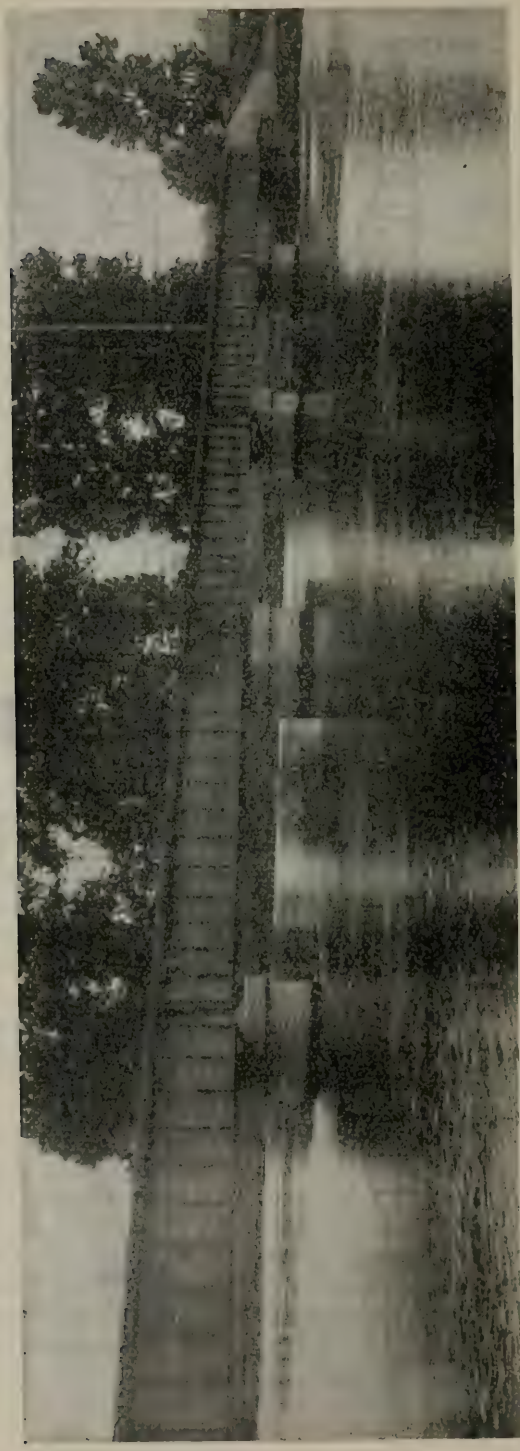


FIG. 7.—TENSAS RIVER DRAWBRIDGE AT FLOOD STAGE.

DRAWBRIDGE OVER BLACK RIVER, NEAR PAROQUET, ARKANSAS.

The former bridge, consisting of one 103 ft. 6-in. combination span and a 206-ft. 6-in. Phoenix draw span on pile piers with trestle approaches, was replaced on the same center line by a 267-ft. draw span on concrete piers and 60-ft. deck plate girder on pile pier, with trestle approaches, both bridges providing for single track.

When the first bridge at this location was constructed the east rest pier was placed on the east bank of the river, which was on the outside of a long curve. The erosion of the current and caving banks moved the bank line east about 85 ft. for about one-half mile above the bridge, with the result that the east rest pier and east trestle approach were located on a point projecting sharply out into the river. This point deflected the current abruptly and caused a swift cross-current through the east channel that made navigation very difficult at this point. The upstream bank of the point was heavily protected by riprap and by piling and heavy timber sheeting.

The pivot pier again deflected the current so as to cause much boiling, whirlpools and eddies immediately below the bridge, which gradually cut back the east bank until it very nearly lined up with the east bank line above the bridge. Further effect of the turmoil was indicated by excessive scour under and downstream from the bridge, causing a depth at low water of about 40 ft., while the average low water depth of the river at other points was about 5 ft.

The effect of the bridge on the current at this point is indicated by the cross-sections. At a point 100 ft. above the bridge the deepest part of the river and swiftest current were about 150 ft. east of the pivot pier, under the bridge they were directly in the main channels on two sides of the pivot pier, while at a point 100 ft. below the bridge they were about 100 ft. west of the pivot pier.

To eliminate the above objectionable conditions it was decided to place the new east rest pier on the east bank line, to excavate down to 8 ft. below low water on the river side of the pier and to construct pile trestle approach 70 ft. long east of the pier, excavating the material and riprapping the slope to prevent scour. As boats had successfully passed through the bridge for a number of years under the objectionable conditions that prevailed, it was thought the straightening of the channel would so improve conditions that very little if any increase in the width of channel opening would be required. The former opening had 86 ft. clear width; the first new plan proposed an opening 90 ft wide, provided by using a through plate girder draw span 210 ft. long. When this plan was submitted to the Engineer Officer it developed that for some years there had been continual complaint by the river interests of difficulty in passing through the bridge, so public hearing was held. At this hearing it was impossible to convince the river men that the

straightening of the channel would be sufficient improvement without a larger opening, and they made very unreasonable demands for a large opening. The Engineer Officer very carefully weighed all the evidence and decided on a reasonable compromise by requiring that the piers

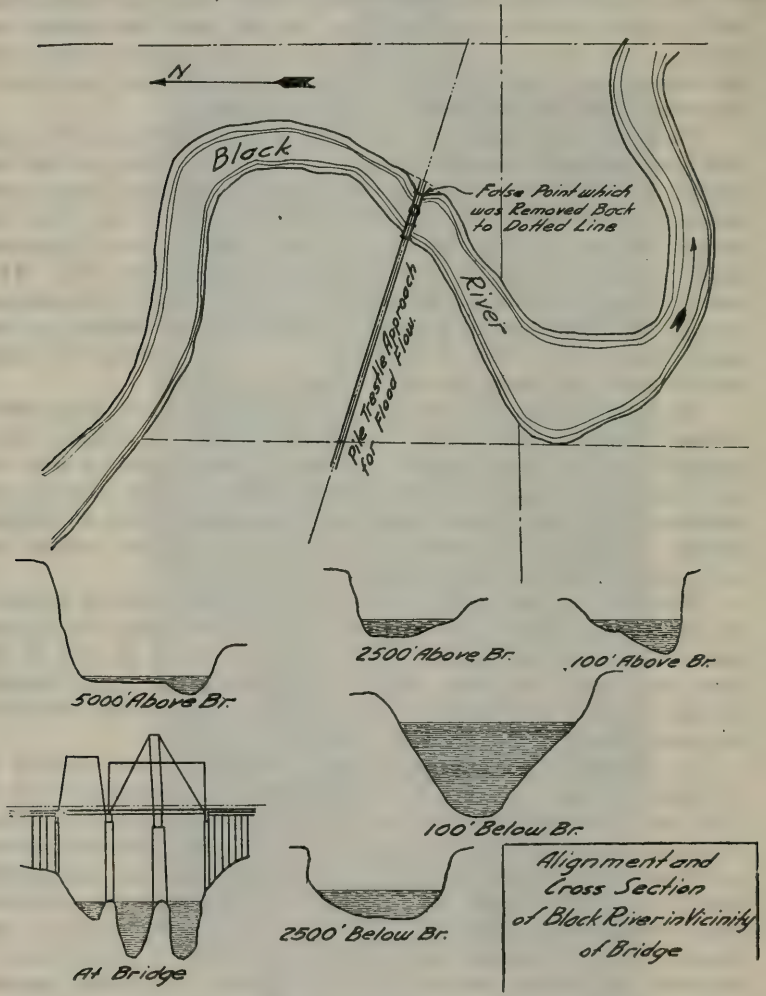


FIG. 8—ALINEMENT AND CROSS-SECTION OF BLACK RIVER IN VICINITY OF BRIDGE.

be placed 135 ft. center to center, calling for a draw span 267 ft. center to center of end bearings and providing clear channels 118 ft. wide. A 60-ft. deck plate girder span sufficed to reach the west bank line and the remainder of the opening was reconstructed as pile trestle.

Placing the new east rest pier on the bank line about 85 ft. east of the old rest pier brought the pivot pier practically in the center of the east channel and the new west rest pier just east of the old west rest pier, the relative location of the old and new piers being such that construction of the new could be completed without interfering with the old except as to the danger from undermining.

The location of the new pivot pier within the east channel effectually blocked that channel to boats, making it necessary for them to

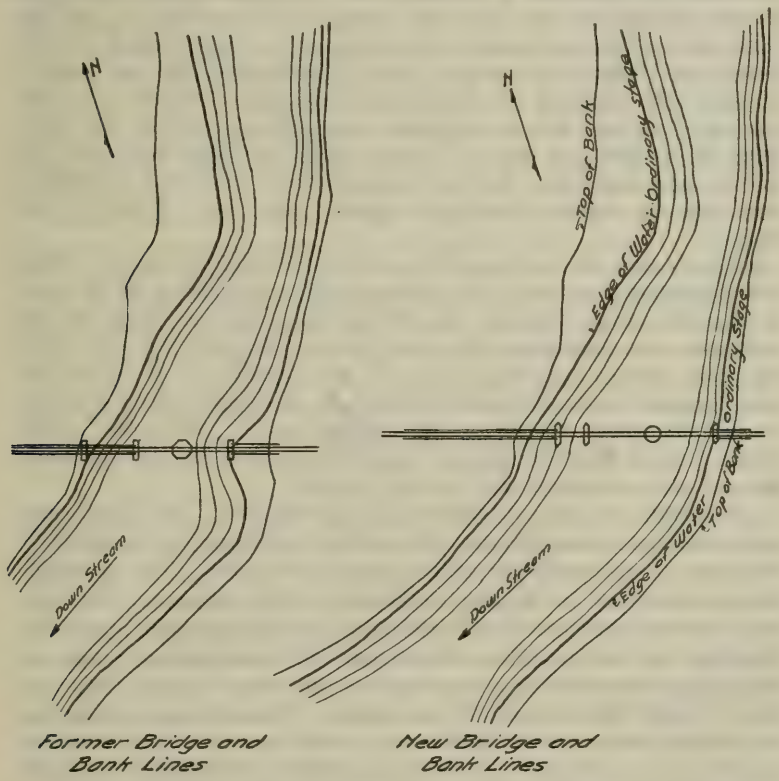


FIG. 9—SKETCH SHOWING LOCATION OF OLD AND NEW BRIDGES WITH REFERENCE TO BANK LINES, BLACK RIVER DRAWBRIDGE.

use the west channel. In that channel the opening temporarily was reduced to 66 ft. after the completion of the new west pier. As it was very difficult for boats to reach and pass through the west channel, the specifications required that the west pier be completed and cofferdam removed down to the top of the footing course before construction of the pivot pier could commence and that during the construction of the pivot pier the Contractor would help boats to pass through the west opening.

It was realized that the work of preparing the new foundations had to be carefully done to avoid damage to the old pile piers. The old west pier had previously settled and leaned toward the draw span about 10 in. and it was necessary to avoid undermining it. No record of the length of piles in the old pivot pier was available, but it was thought that the bottom of the piles was considerably above the bottom of the river in the deep channels on each side of the old pivot pier, the piles being held by the large mound of riprap around that pier. The riprap extended out into the east channel to the location of the new pivot pier and it was necessary to dredge out a large amount of rock before pile driving for that pier could be prosecuted with any hope of success. This dredging and the scour of the channel tended to weaken the old pivot pier, but no movement was noticeable during the work. Later on it developed that the bottoms of the old piles were very high and the piles had only a few feet penetration into the riprap, so little, in fact, that the erection Contractor removed about sixty of them in one day.

Construction of the west pier presented no unusual features. Open crib cofferdam was used, the sinking being accomplished by dredging through the water. Before any attempt was made to pump out the cofferdam, the foundation piles were driven, with the aid of a water jet, to an average penetration of 40 ft., and a depth of 8 ft. of concrete was deposited through a tremie around the pile heads which projected considerably above the top of this sealing course. When the sealing course had set the cofferdam was pumped out, piles cut off 6 in. above the top of the concrete and the pier finished.

The east rest pier is a duplicate of the west pier. The construction was somewhat unusual in that the bottom of footing was required to be placed 57 ft. deep in the solid ground under traffic. The excavation was accomplished by driving pile bents for the support of the track and replacing them by others driven deeper as the excavation progressed. Sheeting was used to reach the bottom of the excavation before the surrounding material was excavated to the water level. This was done to keep the hole as dry as possible. The piles were driven to an average penetration of about 40 ft. with the aid of the water jet and the pier was finished in a manner similar to that used on the west pier.

The construction of the pivot pier was unusual and extremely difficult on account of the swift current in the east channel opening, accompanied by eddies, whirlpools and deep scour, and the large amount of driftwood that reached this opening during every rise in the river.

On account of the great depth of water under and immediately downstream from the bridge, indicating deep scour, the use of pneumatic foundations was discussed. Borings indicated hard blue shale about 130 ft. below the rail, about 100 ft. below average low water and about 125 ft. below extreme high water. Investigation developed that

piles driven into the river bed without the water jet and protected by riprap had supported pivot piers of former bridges at this point for over thirty years without settlement. The Black River is normally throughout its entire length a comparatively quiet stream, and although subject to sudden rise, it does not cut its banks rapidly nor scour to any great depth except where subjected to sudden changes in direction as at the east end of the old bridge. Even if pneumatic foundations were used it would be necessary to protect the east bank above the bridge to prevent cutting and to avoid a recurrence of the bad conditions obtaining at the old bridge. The above facts led to the decision to use pile foundations instead of going to the heavy expense of pneumatic work. In addition it was confidently expected that cutting away the point at the east end of the bridge would restore conditions to normal and cause much sediment to deposit and fill up the deep holes eroded by the turmoil in the current, and this filling started immediately after the current was permitted to pass unobstructed.

It was expected that during the construction of the pivot pier more scour would take place and it was difficult to decide how deep to place the footing of this pier. It was finally decided to extend the neatwork 8 ft. below low water and to make the footing 10 ft. deep, placing the bottom of footing 57 ft. below rail. Any space below that level caused by scour was to be filled with riprap. It was impossible to foretell how deep the river would scour when the channel were further obstructed by a large cofferdam, or to what extent the old piers would be endangered. The contractor decided to drive the foundation piles and place the riprap around them before placing the cofferdam.

The piles were driven with the aid of a water jet to an average penetration of 40 ft. below the bottom of the footing. Long piles were used to avoid the necessity of following them down through the water, which would have been very difficult, as the deep water and swift current rendered it almost impossible to hold short piles with followers. After the piles had all been driven, which, as a rule, placed the tops of the piles level with the water surface, the piledriver barge was equipped with a circular saw revolving in a horizontal plane and attached to the bottom of a vertical shaft which was held and guided by the piledriver leads. This saw cut off all the piles about 16 ft. below the water surface.

After the piles had all been driven and cut off under water about 2 ft. above the bottom of the footing course, the riprap was deposited among and around the piles up to about one foot below the bottom of the footing and forming a shoulder about 5 ft. wide all around the piles. On top of this a layer of "pit run" gravel about one foot thick was placed to bring the level up to the bottom of the footing. The cofferdam (open timber crib construction) was then launched and landed on top of the layer of gravel. About 8 ft. of concrete was then placed by means of bottom dump buckets, allowed to set, coffer-

dam pumped out and pier finished in the ordinary manner. Riprap was later deposited around the footing course, making a shoulder about 5 ft. wide entirely around the pier. The expectation that the river would deposit material to fill the deep holes has been realized and the riprap is now deep within the bed of the river.

The pivot pier was built cellular to reduce the weight on the pile foundation. The rest piers were built solid.

The specifications for erection provided that the expense of caring for navigation would be borne by the Railway Company. It was calculated that the falsework could be placed, the old span taken down and the new span erected and adjusted ready for turning in about six weeks. A canvass among the owners of boats that passed through the bridge indicated that their claims for damages for that length of time would certainly amount to from $15,000 to $20,000, and would probably greatly exceed that sum, as other boats would be drawn by the opportunity.

The large claims that could be foreseen caused the decision to install at the east end between the old and new east piers a second-hand deck plate girder span with timber towers and old rail counterweights for a vertical lift bridge. This was installed ready for operation before the old draw was placed out of service. The completion of the falsework, taking down the old span, and erecting the new draw span, including riveting and adjustment of machinery, out to the temporary lift bridge were carried out at leisure without any interference with boats. At an opportune time the lift span was taken down and the new draw span extended. During the latter operation the river was blocked a few days, which constituted the only time the river was blocked during the reconstruction of the bridge. In spite of all these precautions, however, claim for damage due to delay was filed by the owner of a boat which arrived at the bridge during the final extension of the draw span.

This boat arrived at the bridge at 12:30 p. m. on the 8th and passed through at 5:30 a. m. on the 10th. The total delay amounted to 41 hours, for which claim was made for $5.00 per hour, making a total of $205. It was pointed out to the boat owners that it is customary for such boats to tie up to the banks of these small rivers at night, which reduced the delay to about twenty hours. It was also pointed out to the owners that the same boat and crew had a short time before been employed by the Railway Company for towing purposes at $25 per day for 10 hours' work. On this basis the actual loss was twenty hours at $2.50 per hour, and an offer to settle for $50 was made. Payment of $75 finally settled this claim.

On account of the temporary opening at the east bank being located in the bight of a bend the driftwood that was brought down passed through and caused little trouble except during one rise. One evening when the workmen left the bridge the current was flowing slowly

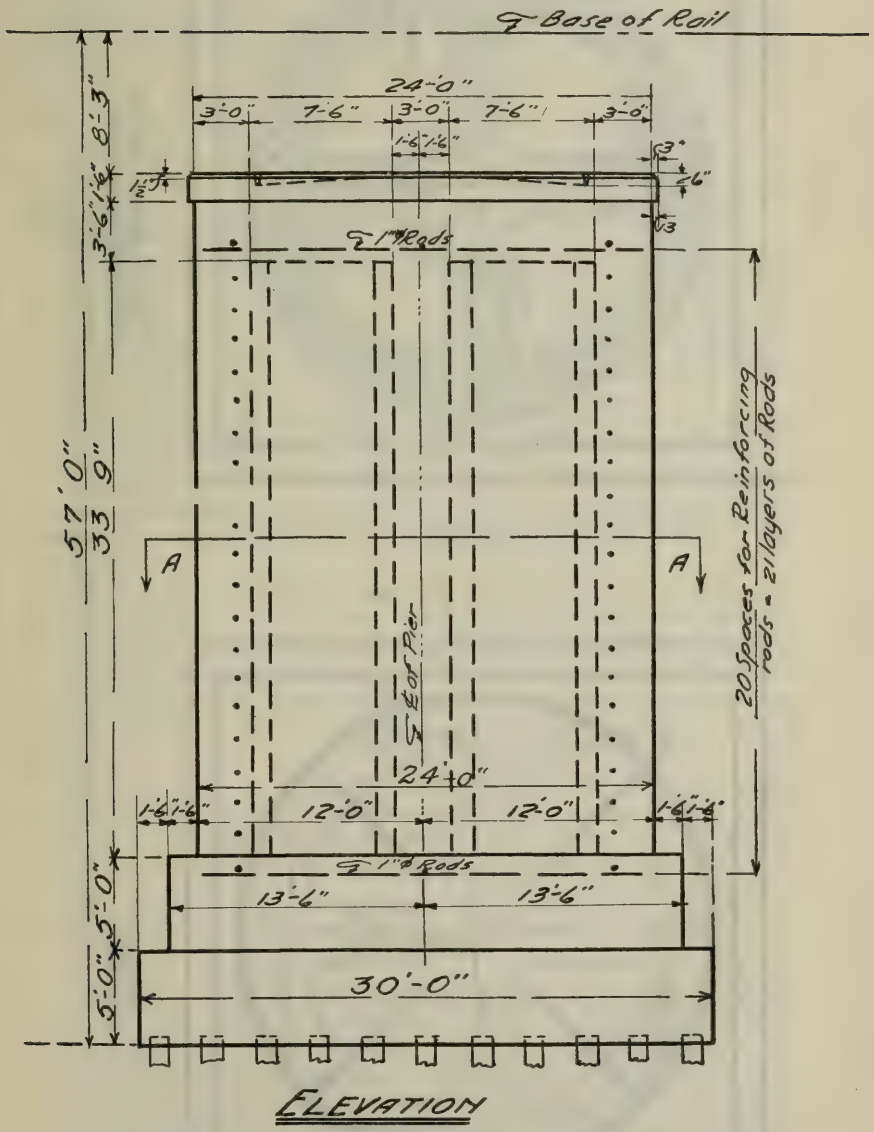


FIG. 10—DETAIL OF PIVOT PIER, BRIDGE OVER BLACK RIVER NEAR PAROQUET, ARK.

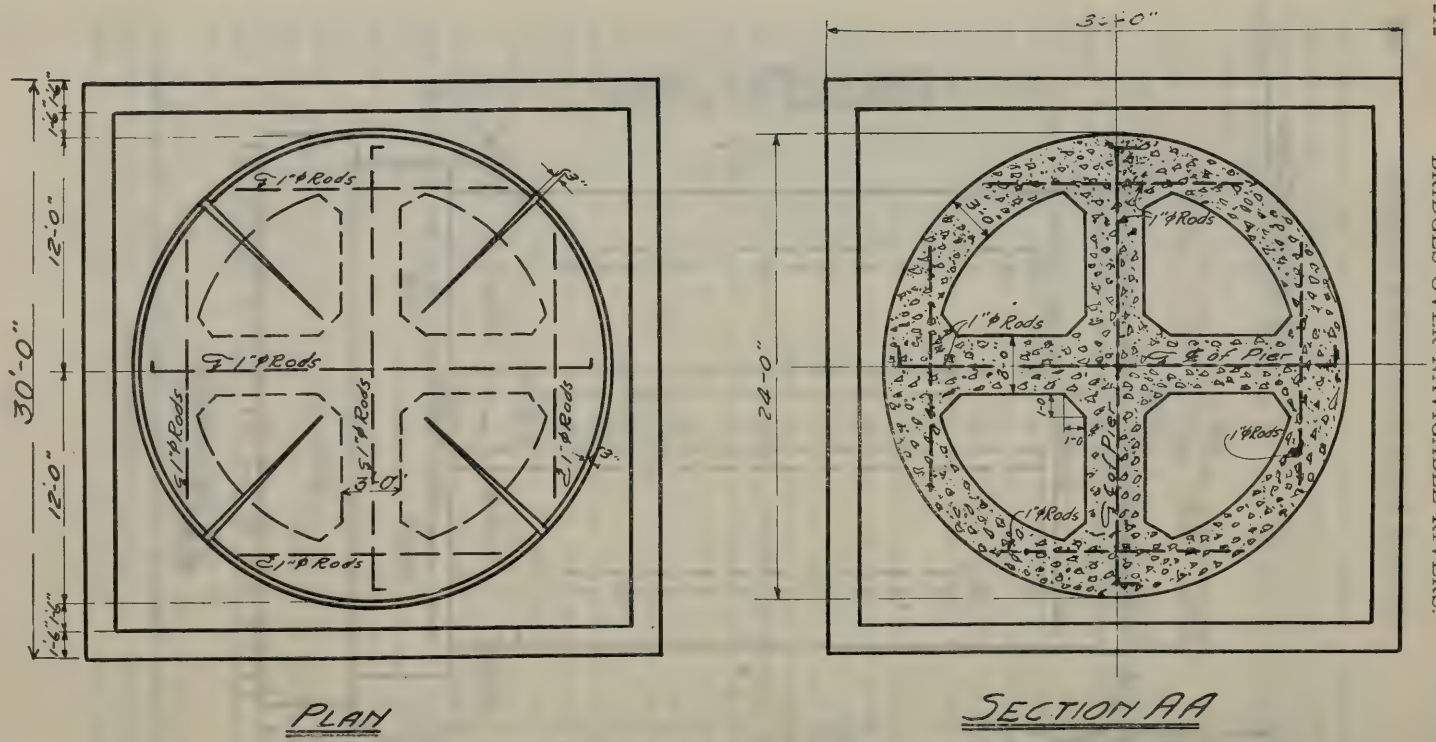


FIG. 10—DETAIL OF PIVOT PIER, BRIDGE OVER BLACK RIVER, NEAR PAROQUET, ARK.

upstream due to backwater, and was overflowing the bank. During the night the water rose high enough to float all logs and other loose timber along the low lands and swamp adjoining the river and then the current turned and brought the entire mass against the falsework, covering the river for its entire width for a half-mile above the bridge. On account of the slow current no damage was done other than the delay; the drift was very readily passed through the falsework.

The erection of the steelwork was let on a unit price basis. The installation and removal of the temporary lift span was an extra, the price being agreed upon in advance between the Contractor and the Railway Company as $1,400.

The opening of the temporary lift span was done by the Contractor on a force account basis. This was found to be very unsatisfactory, as it was always very difficult to separate the cost of this work from the remainder of the job, and it was impossible to determine to what extent the Contractor was entitled to allowances on account of delay to the other work caused by the men having to open the bridge.

In later contracts this difficulty is avoided by getting, in the original bid from each bidder, a price for each opening.

The draw span is a twelve-panel, riveted, disc center-bearing span of ordinary construction operated by a 25-horsepower horizontal Fairbanks-Morse gasoline engine in a reinforced concrete house over the center pier.

The bridge was designed for Cooper's E-50 loading, according to the specifications of the Missouri Pacific Railway, which conform with those of the American Railway Engineering Association. The weight of structural steel is 360 tons, and of machinery 40 tons. The total cost of the bridge, including the excavation of the east bank, removing old bridge and piers and all incidental expense, amounted to about $100,000.

The substructure work was performed by the Missouri Valley Bridge & Iron Company of Leavenworth, Kan.; the steel was fabricated by the McClintic-Marshall Construction Company and erected by the Union Bridge & Construction Company, of Kansas City, Mo.

DRAWBRIDGE OVER WHITE RIVER NEAR AUGUSTA, ARKANSAS.

The former bridge, consisting of one 162-ft. pin-connected through truss span, one 267-ft. pin-connected rim bearing through truss draw span, on masonry pivot pier and steel shell concrete filled cylinder rest piers, two 65-ft. deck plate girder approach spans on pile piers, and pile trestle approaches, was replaced on the same center line by through riveted truss spans, having the same length as the old spans, and two 60-ft. deck plate girder approach spans, the cylinder piers having been converted into ordinary masonry piers, as described hereinafter. Both old and new bridges were designed for single track.

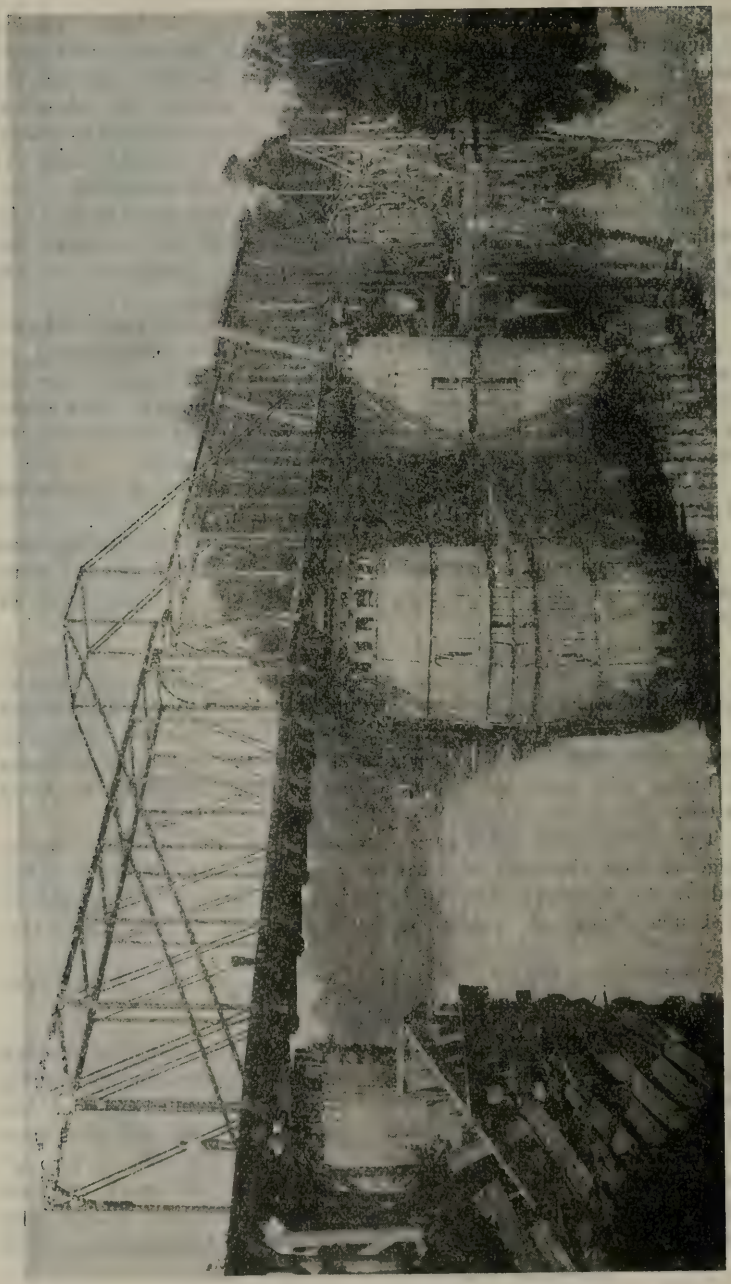


FIG. 11—BLACK RIVER DRAWBRIDGE AT COMMENCEMENT OF RECONSTRUCTION.

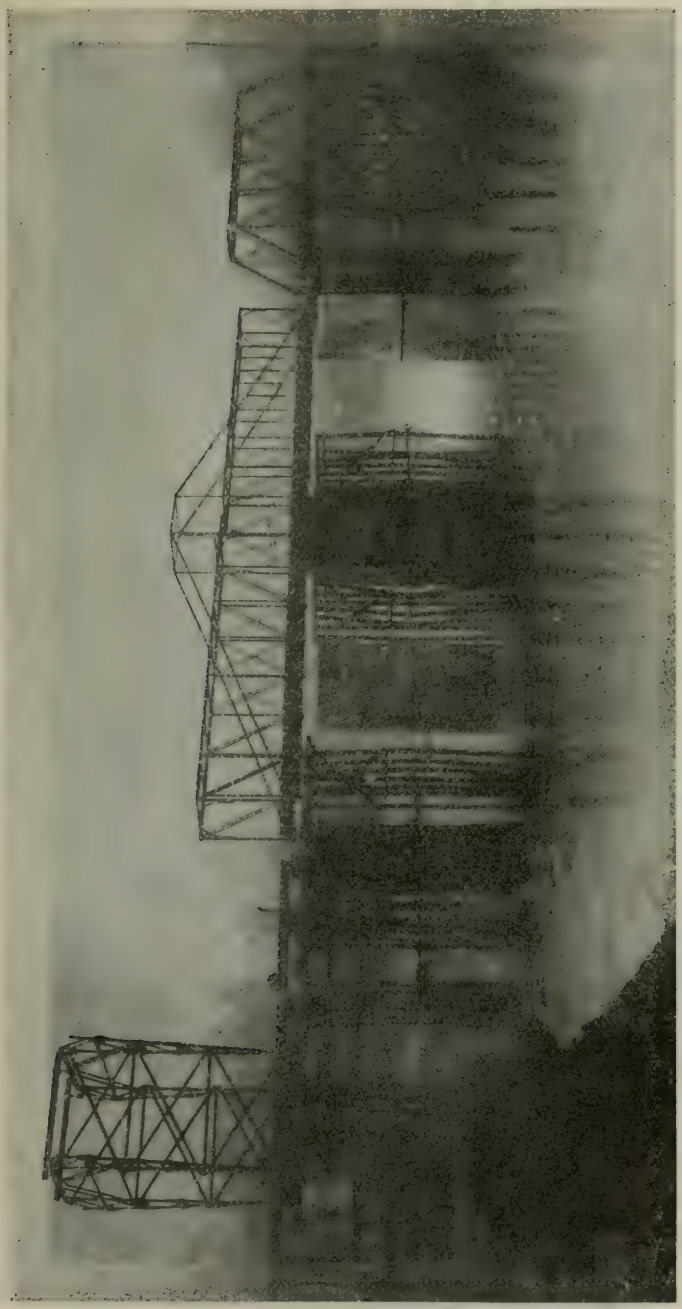


FIG. 12—BLACK RIVER DRAWBRIDGE AFTER COMPLETION OF NEW PIERS AND PART COMPLETION OF FALSEWORK, BEFORE INTERFERING WITH OLD DRAW SPAN

FIG. 13—BLACK RIVER DRAWBRIDGE AFTER INSTALLATION OF TEMPORARY DECK GIRDER LIFT SPAN. TRAVELER READY TO TAKE DOWN OLD DRAW SPAN.

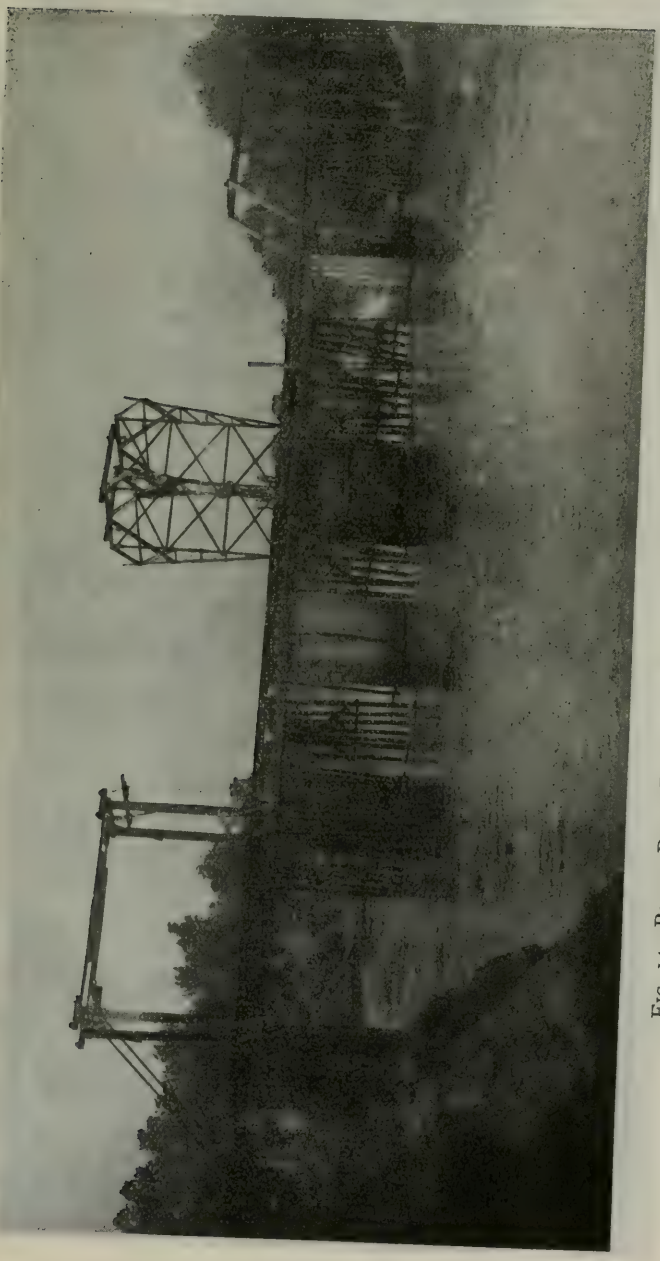


FIG. 14—BLACK RIVER DRAWBRIDGE AFTER TAKING DOWN OLD DRAW SPAN.

FIG. 15—BLACK RIVER DRAWBRIDGE AFTER ERECTION OF ONE ARM AND PARTIAL ERECTION OF OTHER ARM EXTENDING TOWARD TEMPORARY LIFT SPAN.

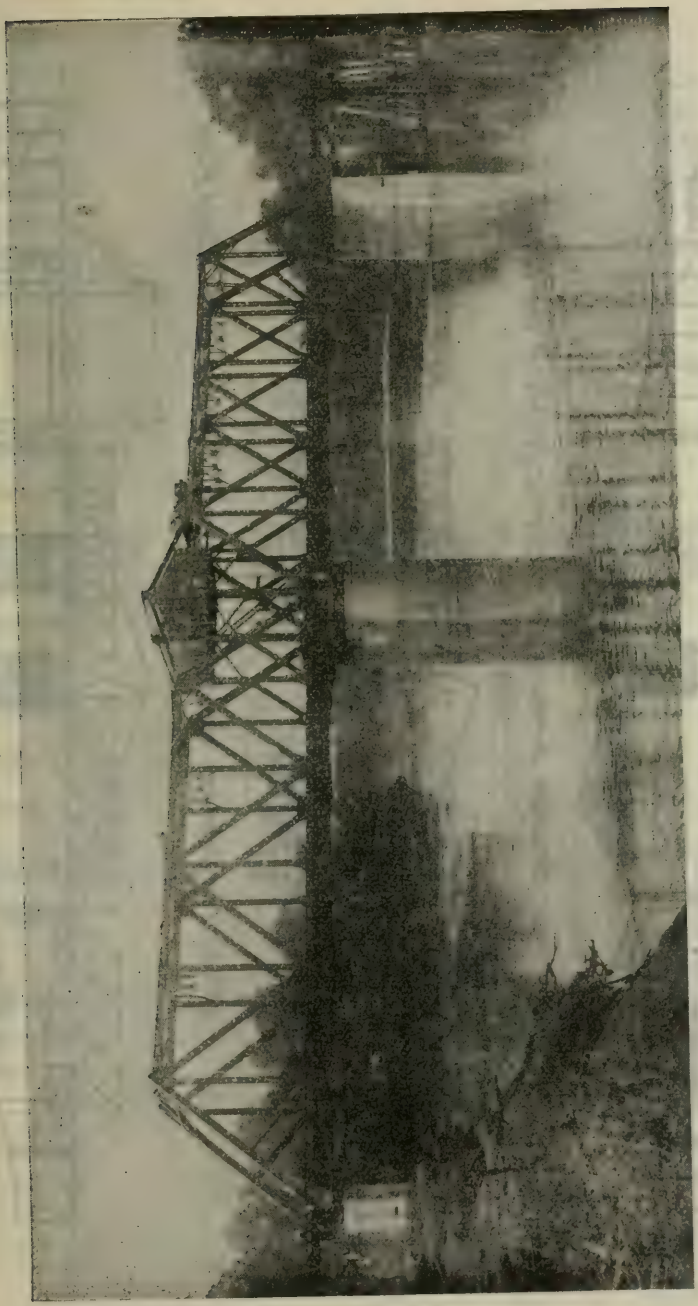
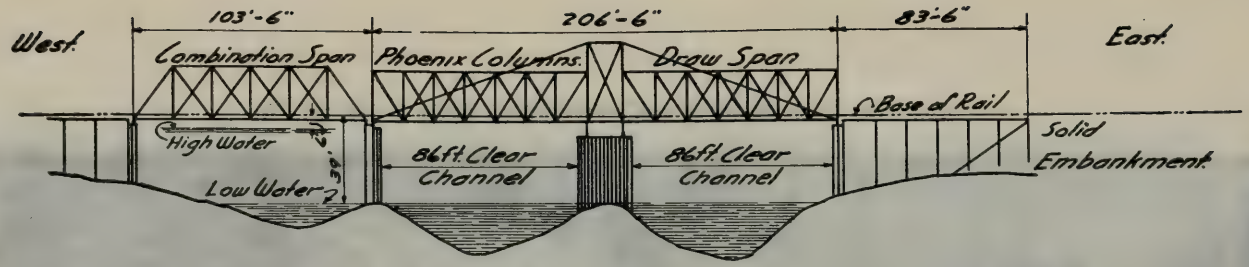
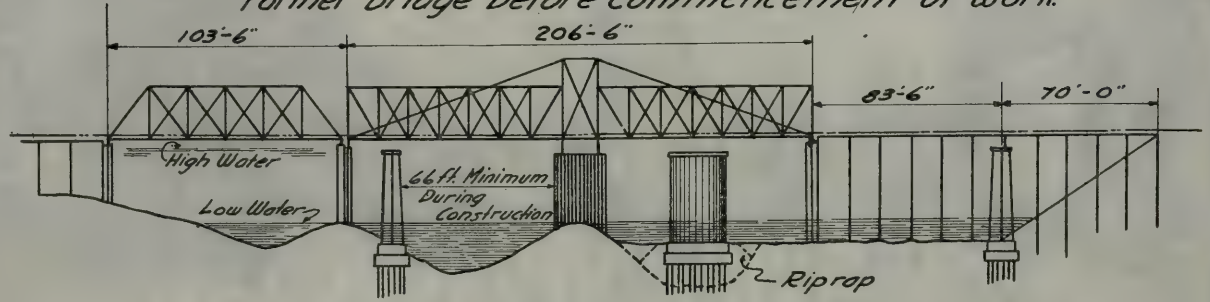


FIG. 16—BLACK RIVER DRAWBRIDGE UPON COMPLETION OF ERECTION.



Former Bridge before Commencement of Work.



After Completion of New Piers and Extension of East End.

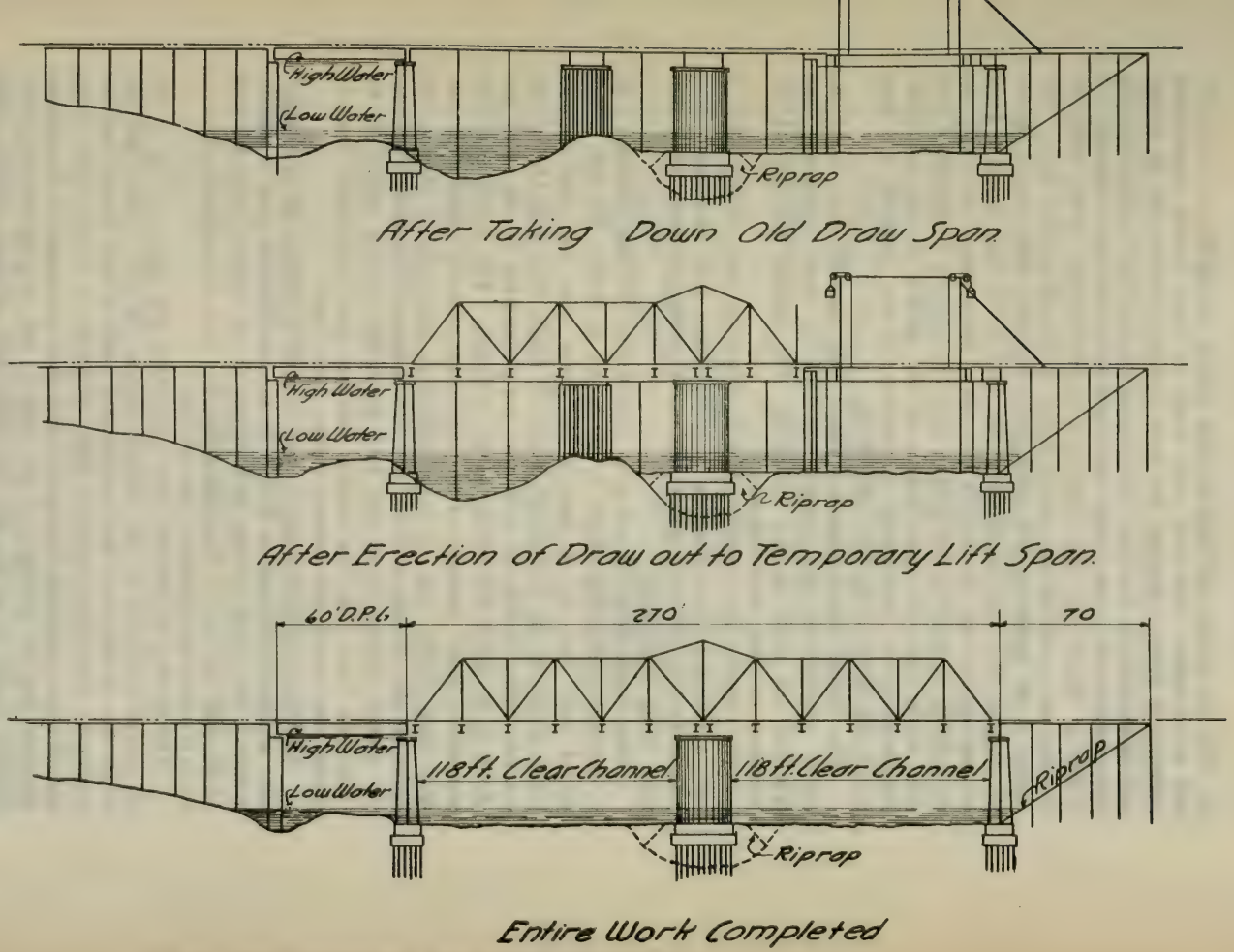


FIG. 17—SIDE ELEVATION OF BLACK RIVER DRAWBRIDGE

The old bridge had been in place twenty-six years when replaced, and no complaint had ever been made of boats having experienced difficulty in passing through the draw openings. Practically no change had taken place in the bank lines during that period, consequently the plan prepared for new bridge contemplated no change in location or length of draw span, but required a slight decrease in the width of the channels to permit the reinforcement of the old cylinder piers. The change in the length of deck plate girder approach spans was made for the purpose of permitting the new pile piers to be constructed in front of and in the clear of the old pile piers; these spans are simply for the purpose of spanning the sloping banks in which it is difficult to hold pile trestle, and the exact length of the girders is not important. Abutments were unnecessary on account of the necessity for long trestle approaches to accommodate floods.

The United States Engineer Officer held that the very slight decrease proposed in clear opening was not of great importance, and approved the plans as first prepared. The formal approval of the Secretary of War soon followed.

The substructure reinforcement proposed at this bridge was of such a nature as to necessitate no interference with navigation, as it was decided to carry the spans and traffic on the old piers while they were being reinforced.

Each of the three old rest piers consisted of two steel cylinders 7 ft. in diameter, extending down 55 ft. to 60 ft. below the rail, which placed them about 15 ft. deep in the sandy river bed, each cylinder being supported on 7 piles, the heads of which were imbedded in the concrete filling within the cylinder; the penetration of the piles was about 14 ft. below the bottom of the cylinders. The writer has never met with a better example of the supporting power of sand when confined than in the case of these cylinders; according to our present standards the cylinder piers did not have sufficient supporting power for the former bridge which they had supported without settlement for twenty-six years. It was decided, however, not to overload them by placing the newer and heavier bridge upon them.

Additional supporting power was secured by driving 56 new timber piles within a cofferdam 14 ft. x 35 ft. surrounding each pair of the old cylinders, the piling having been driven to an average penetration of 35 ft. with the aid of the water jet. The new piles extend down 15 to 20 ft. below the bottom of the old piles.

The driving of the first new foundation pile with the aid of the jet caused settlement of the cylinder nearest the pile. Alarm was felt when this trouble was first encountered until it was found that the settlement immediately stopped with cessation of driving and jetting and the pier remained stationary until their resumption. Experiment disclosed that the driving of a pile with the aid of a jet near the other cylinder would cause the pier to right itself, although slightly lower than formerly. The actual height of the tops of the old piers was no

longer of any importance, so driving was resumed. Piles were driven alternately at one end, then at the other, as the necessity for righting the piers arose. The tipping was permitted to go on until the tops of the piers were three inches out of line, when the driving would be

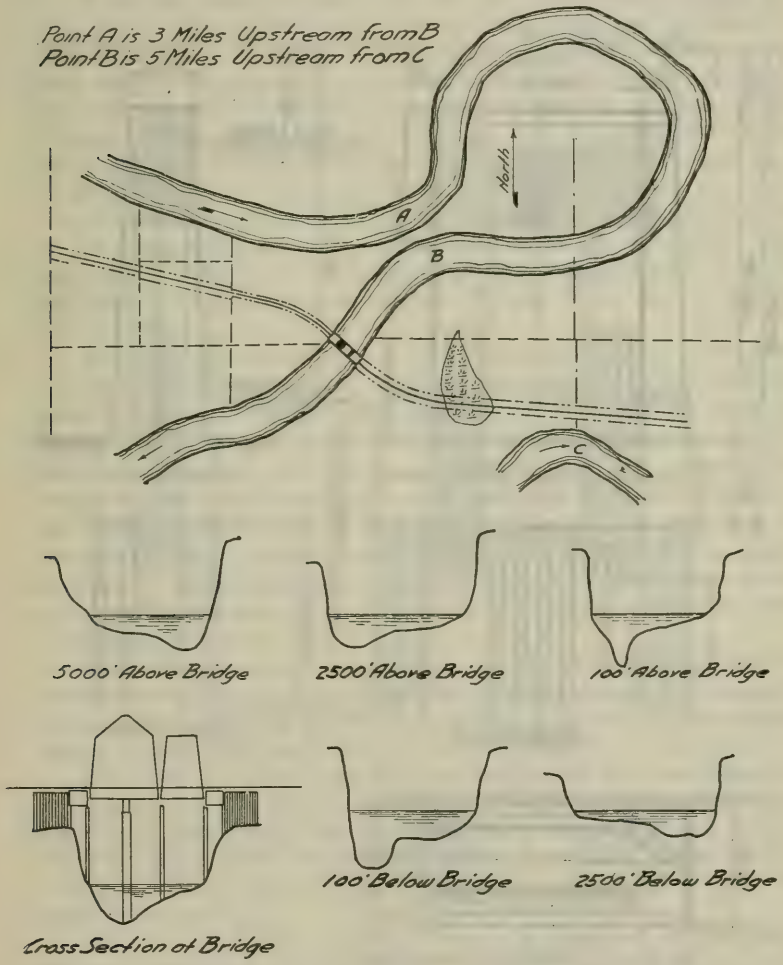


FIG. 18—ALINEMENT AND CROSS-SECTION OF WHITE RIVER IN VICINITY OF BRIDGE.

changed to the other end until the pier became three inches out of line in the other direction. No trouble was encountered in the location of the piers in the direction of the bridge, practically no motion in that direction having been detected. This was probably due to the fact that they were guided in their settlement by the weight and stiffness of the spans resting on them.

A small amount of difficulty was encountered in keeping the track in condition for operation. The easiest condition was found at the east pier, which supported the east end of the 162-ft. approach truss

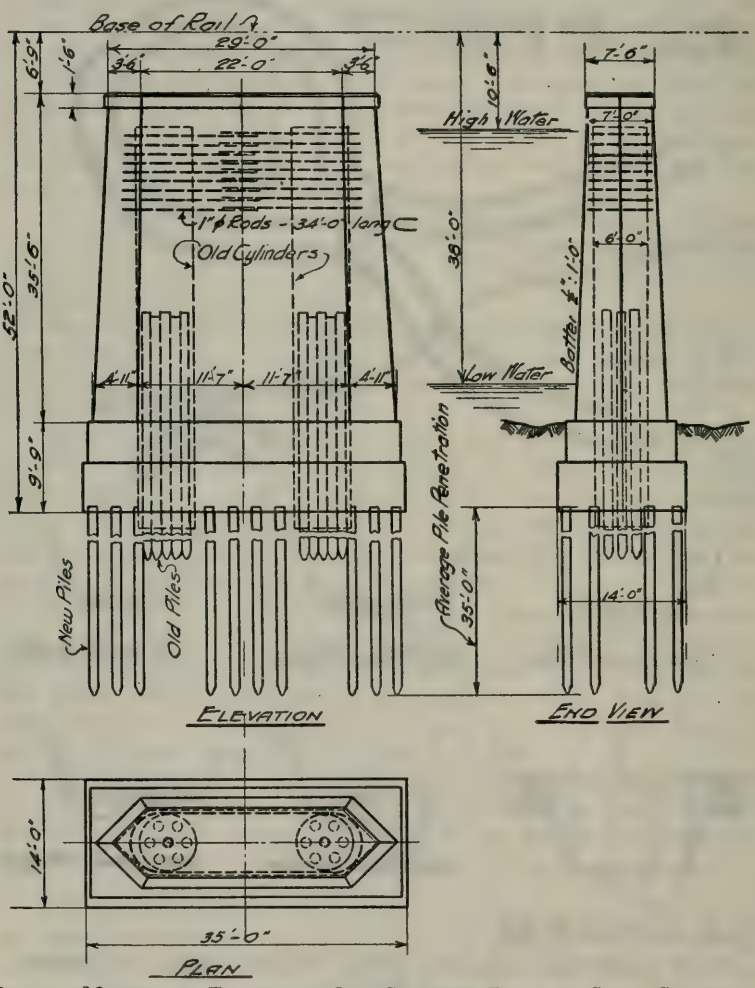


FIG. 19—METHOD OF EMBEDDING OLD CYLINDER PIERS IN SOLID CONCRETE PIER, DRAWBRIDGE OVER WHITE RIVER, NEW AUGUSTA, ARK.

span and the west end of the girder span. Here the ends of the spans were permitted to move from side to side and down with the pier.

At the west pier, which supported the west end of the draw span and the east end of the girder span, the draw span was permitted to

swing free from the pier and the end of the girder span followed the top of the pier when it moved. Here it was necessary to keep the end of the girder span in line and level with the end of the draw so that trains could always cross. The ends of the draw span were supported on oak wedges during the passage of trains.

At the pier which supported the east end of the draw span and the west end of the approach span, the approach span was permitted to move from side to side and down with the pier, while the end of the draw span swung free. Track connection at the end of the draw span was maintained by shimming under the bridge ties on top of the stringers at the end of the approach span and by sliding the bridge ties from side to side on top of the steel stringers of the approach span by the assistance of steamboat ratchets.

After the completion of driving at each pier the spans were jacked up and over, where necessary, to bring track to line and level. The work was delayed very little by the necessary adjustments to track and spans. The maximum settlement of any pier during the pile driving was 13 in.

Before the commencement of work considerable riprap surrounded the old cylinder piers, and this riprap was expected to interfere with the placing of the cofferdams. This material was excavated by dredging around the old piers down to the bottom of footing, after which the sheet pile cofferdams, and then the foundation piles, were driven. The sand that was brought up by the jets and other sediment within the cofferdams was then removed by a sand pump and the lower portion of the concrete footing placed around the pile heads under water by means of a tremie. The cofferdams were then pumped out, the piles cut off at the top of the concrete and the piers built in the ordinary manner up to the bridge seats.

The bridge seat course for the east pier was placed during erection while the east truss span was down; the approach girders and falsework stringers were supported on the new concrete below, the supports being moved to permit the completion of the new bridge seat in sections.

The draw rest piers were also completed while the east span was under erection. The cylinders of these piers were cut down and crossover beams placed while the draw span was swung. The ends of the crossover beams were supported on frame bents that rested on the footing projections of the piers. The bridge seats were finished off under the beams.

The question, "Why was the bridge not supported on falsework during this work on the foundations?" naturally presents itself. This was considered and also the advisability of taking down the old piers, but the fear of losing the falsework and spans in a flood caused the determination to go ahead as described. The White River is subject to sudden rise and carries much driftwood at high velocity. When this driftwood comes in contact with falsework it accumulates too rapidly

to be successfully removed, with the result that it makes a mat extending the entire length of the falsework from water surface down to the bottom of the river. The pressure of the current is great and the scour of the current going under the drift very dangerous. The accumulation usually results in the bents being pushed out of line or being undermined, either condition resulting in delays to trains.

The files disclosed that in the reconstruction of another bridge across this river the above condition caused so much damage to the falsework that the bridge was out of service for about two weeks, during which time all trains were compelled to detour.

It was realized that partial falsework could have been put in and protected by floating booms, but that would have interfered with the floating equipment of the foundation Contractor.

The old pivot pier was of ordinary solid masonry construction supported on grillage and piles, the piling being heavily protected by riprap; no settlement or other trouble had ever been experienced. As the former draw span was rim bearing and the new draw pivot bearing it was decided to remove the coping (using the stone for additional riprap around the footings) and replace it with a thicker slab of reinforced concrete designed to distribute the load from the new span uniformly over the pier, this reinforced concrete coping being placed between the taking down of the old draw span and the erection of the new. The experience in attempting to adjust claims from boat owners for the closing of the Black River indicated that it would be best to make provision for navigation continuously during erection. The Contractor was awarded a unit price per ton for the erection of the steel, a lump sum for installing a temporary deck girder lift span, and a fixed price for each time he had to open the bridge.

At this bridge towers and counterweights were not installed, but arrangements were made to lift the entire span out by the erector's derrick car which would move back with the span. Although no trouble had been experienced at Black River it was seen that on account of the limited amount of lift that could practically be provided at reasonable expense on temporary supports, the arrival of a large boat at extreme high water might find the lift span in its highest position too low, and it was to avoid such a contingency that the span was handled with a derrick car at White River.

Unusual high water obtained for long periods during the entire reconstruction. The substructure work was delayed by high water during the ordinary low-water period so that the erection started immediately before the ordinary high-water period, making it necessary to put in and maintain falsework during high water. Falsework was first placed under the 162-ft. east approach span, the old span taken down and the new span erected. On account of this being a riveted span, the falsework was used longer than usual, as the span could not be swung free until all connections except direct compression splices had been

fully riveted. While the riveting was under way the river rose and carried much driftwood against the falsework, where it accumulated in spite of the efforts to keep it going. Upon completion of the riveting this falsework was removed at once; all the blocking and stringers and all but three bents were successfully removed by the bridgemen, those three bents having been pushed horizontally out from under the bridge without tipping by the pressure of the drift and undermining of the piles. Immediately below the bridge the bents tipped over, mingled with the driftwood and passed on down the river.

Falsework was next placed under the west arm of the draw span and the accumulation of driftwood was such as to necessitate taking unusual precautions. To hold the falsework temporarily a steel cable was passed through the bents in a long curve, the ends of the cable being attached to the upstream ends of the pivot and west piers.

An opening 50 ft. wide was left in the east draw channel just west of the east rest pier and a heavy pile bent was driven for the support of the temporary girders to be used for spanning that opening. Heavy pile bents were also constructed on each side of the pivot pier for the support of a deck girder span over that pier to facilitate the reconstruction of the coping course. To prevent more drift from accumulating against the falsework a floating boom was constructed reaching from the west pile pier of the temporary channel opening to a tree on the west bank of the river about 1,000 feet upstream from the bridge. The boom consisted of a 1-in. steel cable to which was attached a line of 60-ft. large cypress piles, a surplus of which was on hand for use in case of emergency.

The boom did more than was expected of it. The angle between it and the current was so slight that all the large driftwood followed the boom down to the temporary opening and passed through. The small portion that passed under the boom caused no trouble whatever.

When everything was in readiness a quick change was made by removing two panels of the old draw span at the east end and installing the temporary girder span over the channel. This change consumed about two days and no boats were delayed. The dismantling of the old span, reconstruction of the pivot pier and erection of the new span out to the temporary channel was carried out carefully with the realization that unusual speed was not necessary. It was the first intention to erect and rivet up the west arm of the draw as a simple span and to remove the falsework from under that arm before completing the erection of the draw. The floating boom was so effective, however, that this was not necessary. The draw was erected and riveted with the exception of the two east panels, after which another quick move was made in the removal of the temporary deck plate girder span and completion of the erection of the draw span, which was ready for turning a few days after the deck girder span was removed.

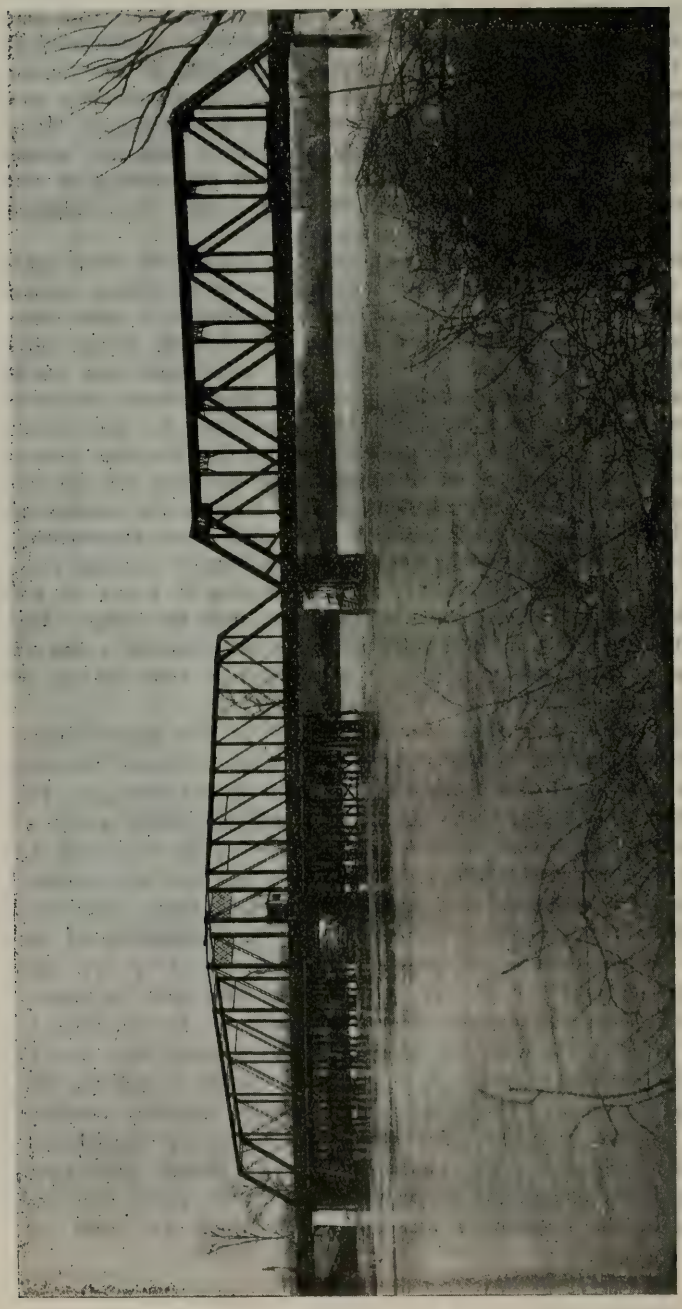


FIG. 20.—WHITE RIVER DRAWBRIDGE AFTER COMPLETION OF NEW APPROACH SPAN AND PARTIAL COMPLETION OF FALSEWORK UNDER DRAW SPAN.

FIG. 21.—WHITE RIVER DRAWBRIDGE AFTER REMOVAL OF OLD DRAW SPAN. TRACK CARRIED OVER PIVOT PIER AND TEMPORARY OPENING BY DECK GIRDERS.

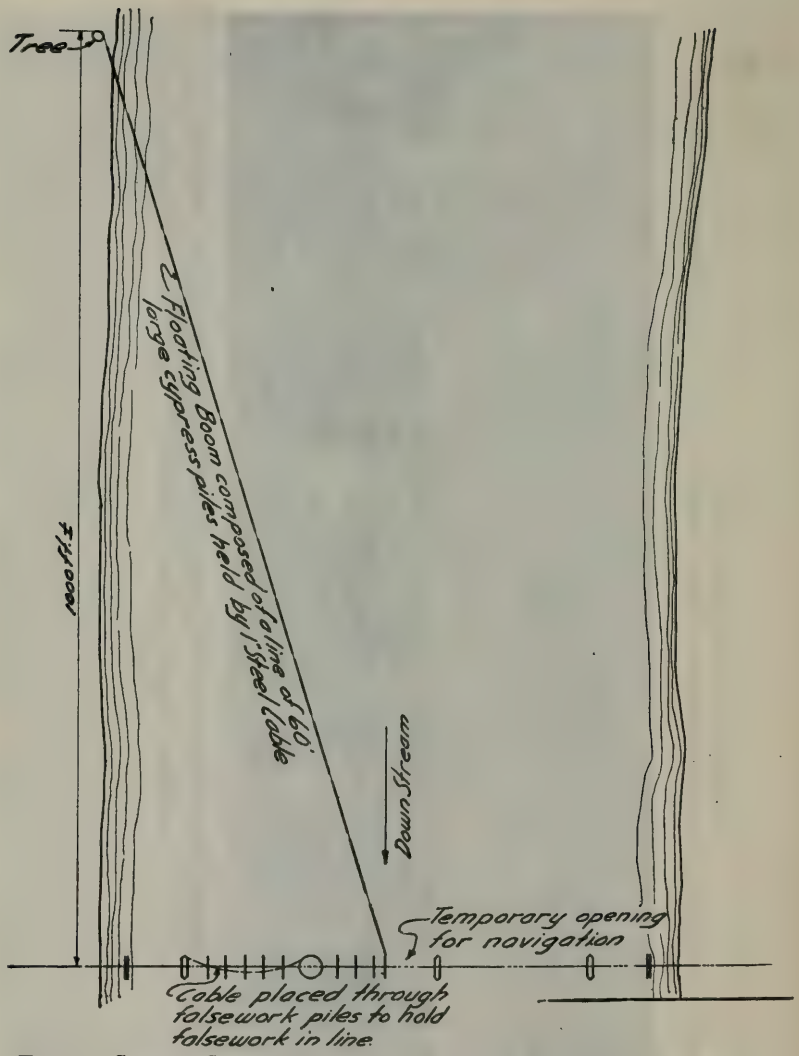

Tree
Floating Boom composed of a line of 60' large cypress piles held by 1" steel cable
Fir tree
Down Stream
Temporary opening for navigation
Cable placed through falsework piles to hold falsework in line.

FIG. 22—SKETCH SHOWING LOCATION OF CABLE TO HOLD FALSEWORK IN LINE AND FLOATING BOOM TO DEFLECT DRIFTWOOD FROM FALSEWORK, WHITE RIVER DRAW, NEW AUGUSTA, ARK.

The new deck plate girder spans were installed at odd times during the erection. During the final extension of the new draw span over the temporary channel the river was out of its banks and this high water made it possible to permit boats to pass through the end openings, the east deck girder span being removed for that purpose when necessary.

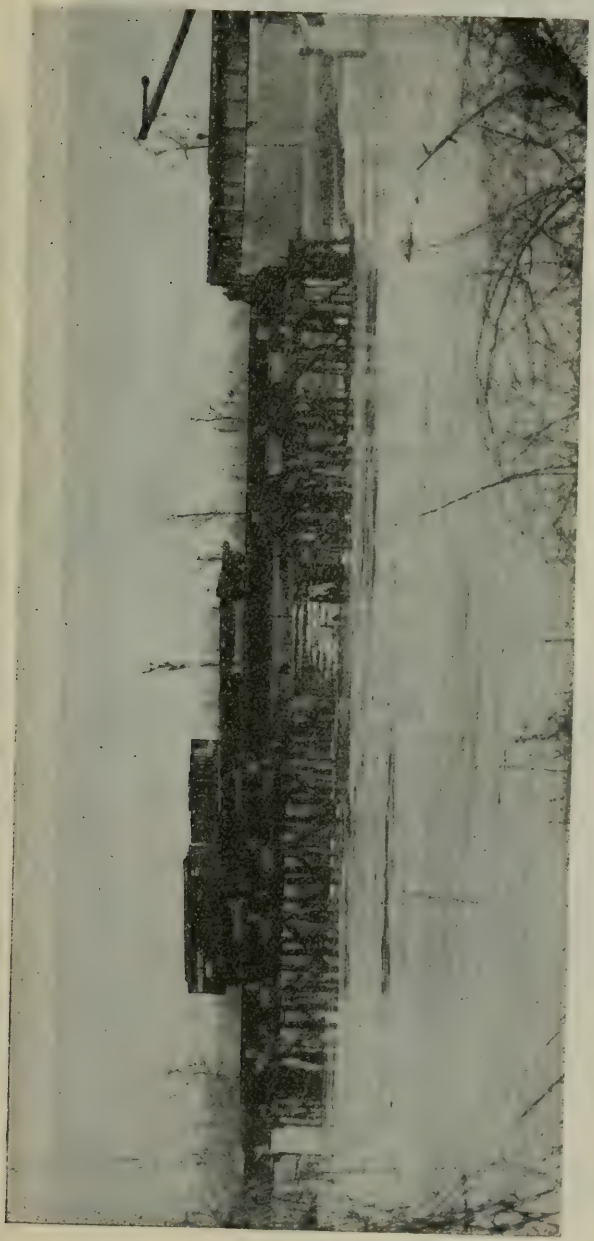


FIG. 23—WHITE RIVER DRAWBRIDGE SHOWING BOOM OF DERRICK CAR RAISING TEMPORARY GIRDER LIFT SPAN TO PERMIT BOAT TO PASS THROUGH BRIDGE.

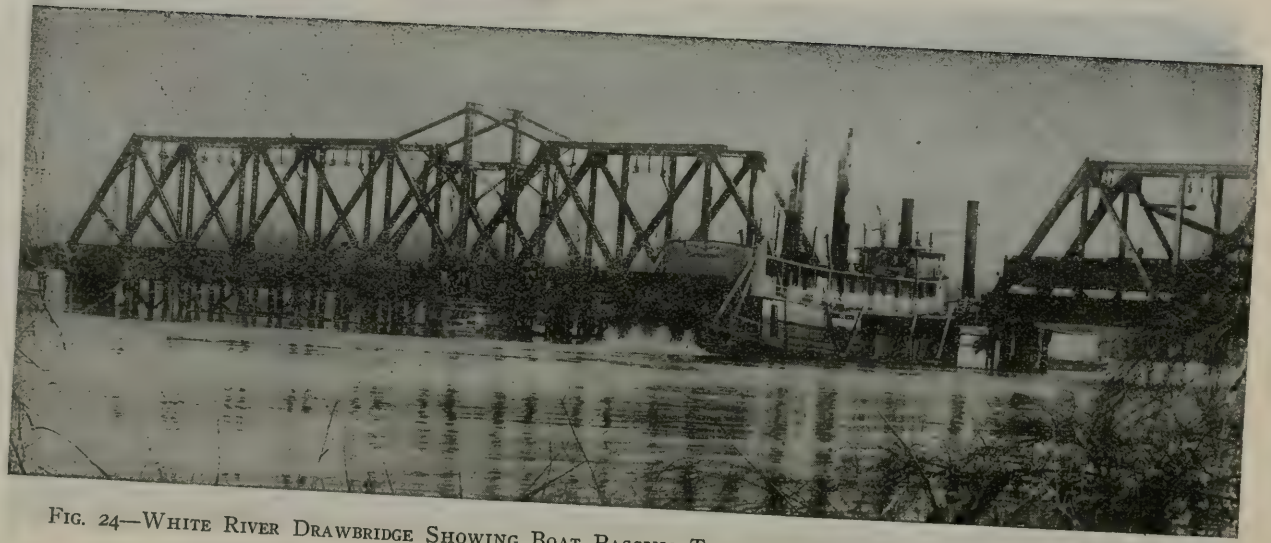


FIG. 24—WHITE RIVER DRAWBRIDGE SHOWING BOAT PASSING THROUGH TEMPORARY OPENING. LIFT SPAN IS SWINGING FROM BOOM OF DERRICK CAR INSIDE OF APPROACH SPAN. NEW DRAW SPAN COMPLETED OUT TO TEMPORARY OPENING.

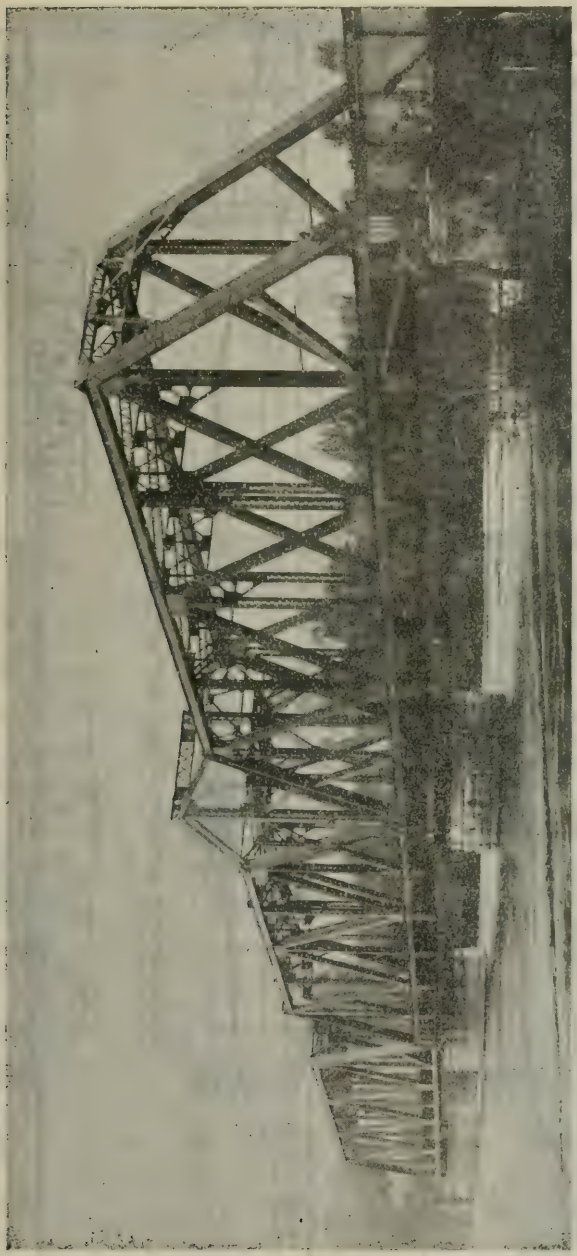
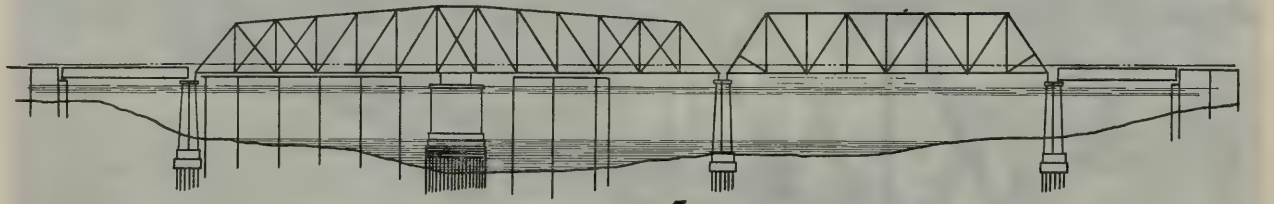
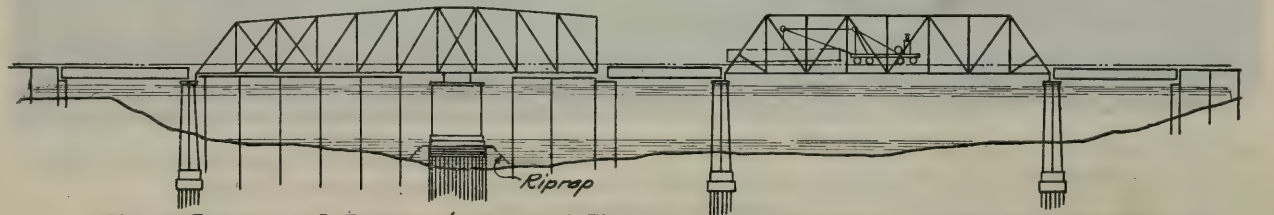


FIG. 25—WHITE RIVER DRAWBRIDGE UPON COMPLETION OF ERECTION.

Old Bridge before Commencement of Work.



Falsework under Draw after Erection of New East Span.



Three Panels of Draw down and Temporary Girders in over Channel Opening

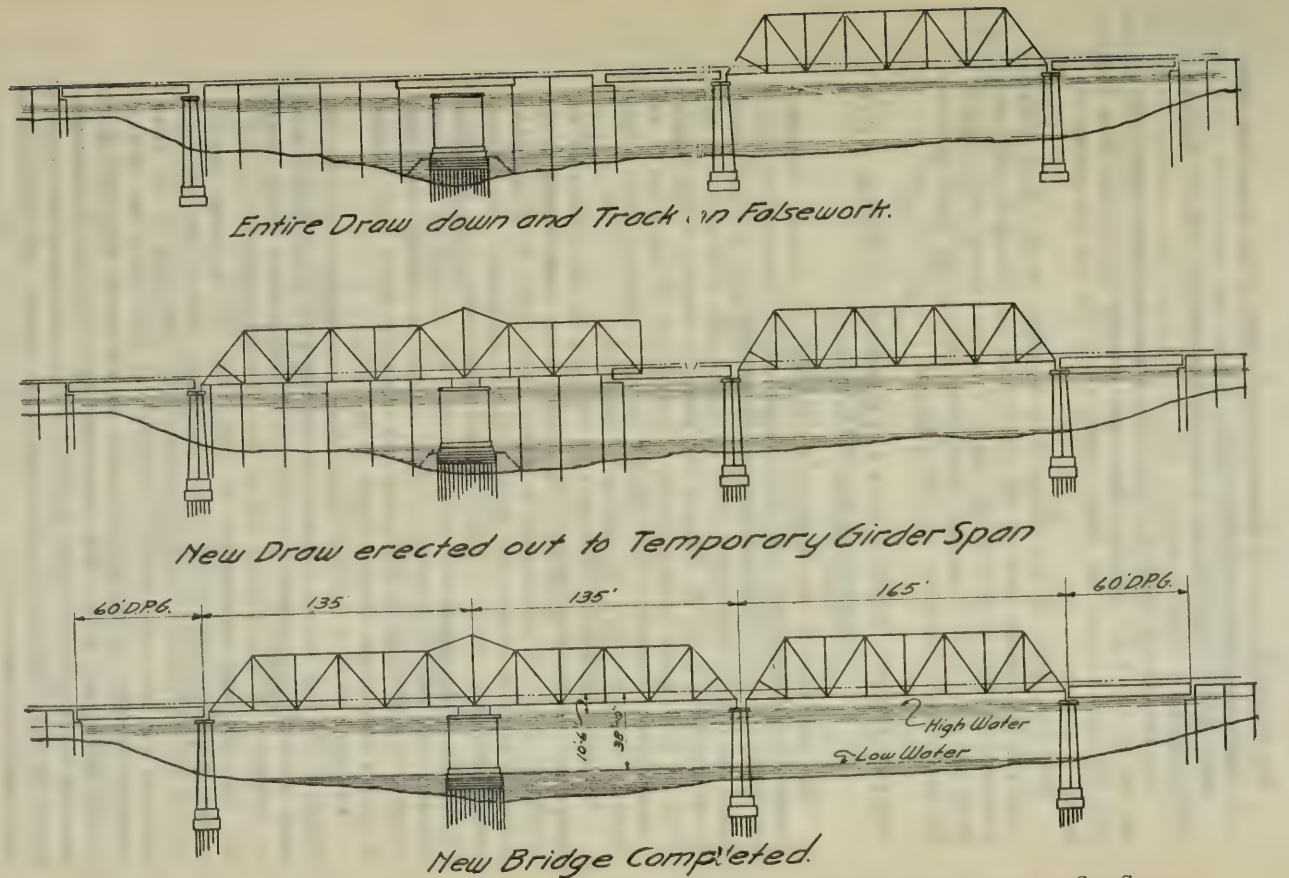


FIG. 26—SIDE ELEVATION OF BRIDGE NO. 18 OVER WHITE RIVER NEAR NEW AUGUSTA, ARK., IN SIX STAGES.

The installation of the temporary deck plate girder span over the east temporary channel cost about $400.

Each time the bridge was opened during erection cost the Railway Company $10.

For a period of about five years this bridge had been opened from five to ten times per month. During the erection of the new draw it was necessary to open the bridge nearly every day for the passage of boats.

The draw span of this bridge is a duplicate of the Black River draw and the various parts of the work were carried out by the same Contractors. The weight of the 162-ft. through riveted truss span is about 200 tons, and of the two 60-ft. deck plate girder spans 50 tons. The total cost of the bridge was about $90,000.

VERTICAL LIFT BRIDGE OVER ST. FRANCIS RIVER NEAR MARIANNA, ARKANSAS.

The new line of the Missouri Pacific Railway between Memphis, Tennessee, and Marianna, Arkansas, crosses the St. Francis River about fifty miles from its confluence with the Mississippi. At favorable water stages the largest Mississippi River steamers with large tows can and do navigate this lower St. Francis, the principal industry being logging. Tows of four barges abreast having a total width of about 125 ft. are comparatively frequent. The highest part of some of the largest steamers is 65 ft. above the surface of the water.

Normally the tops of the banks of the river in the vicinity of the bridge are about 800 ft. apart. The bridge having been located at the mouth of a bayou necessitated a bridge about 1,200 ft. long, which made the location unfavorable from a bridge standpoint. The location being immediately above a rather decided bend in the river was unfavorable from the standpoint of navigation. On account of the latter objection the War Department in 1911 refused to consider any plans whatever for a bridge at this point and requested that a new location be chosen in a longer straight reach of the river.

To secure such a location would have necessitated a considerable change in the line several miles up or down stream, which would have made a decidedly roundabout, instead of a comparatively direct, route to Memphis. It was pointed out to the War Department that when this line was first contemplated in 1903, plans for a bridge at this location had been approved by the Department, right-of-way had been secured and considerable grading completed on both sides of the river (although the line had not been completed at that time) and that a change in location would mean the loss of all money spent for that purpose for several miles. The Department then consented to consider plans for a bridge at this point, provided the movable span were placed exactly at right angles to the direction of the current and ample provision made for boats.

The plans approved by the War Department in 1903 called for a 267-ft. swing draw span that would provide for channel openings 118 ft. wide in the clear. The Act of Congress authorizing a bridge at that time specified that construction must commence within one year and be completed within three years; as that provision had not been complied with the former authority was null and void.

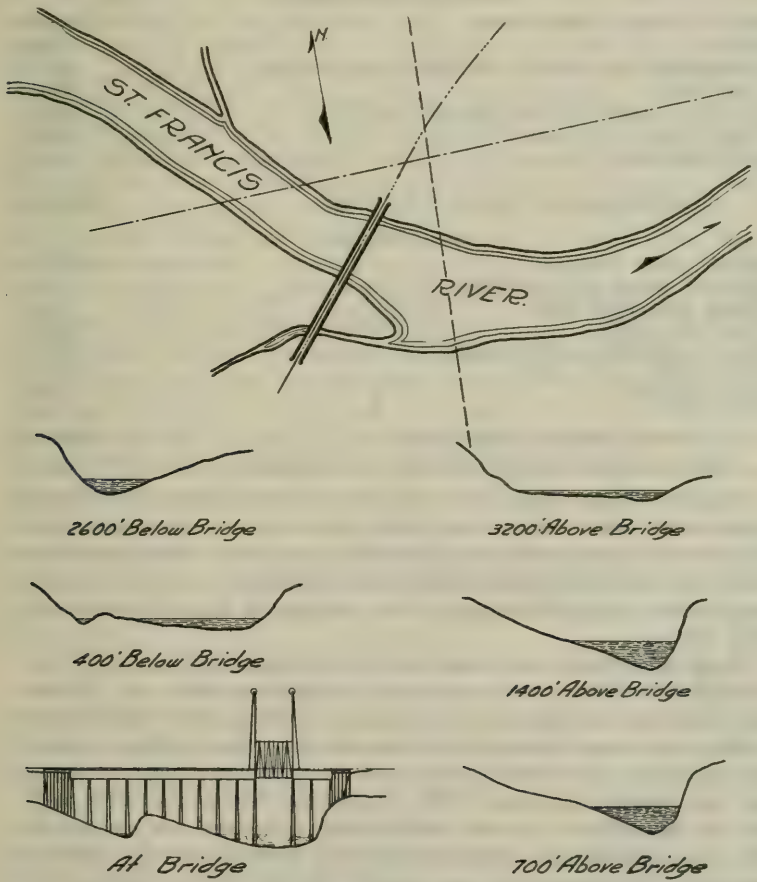


FIG. 27—SKETCH SHOWING ALINEMENT AND CROSS-SECTIONS OF ST. FRANCIS RIVER IN VICINITY OF BRIDGE.

The development of river traffic since that time was such as to call for a larger opening; a width of not less than 150 ft. being finally decided on. As the remainder of the bridge could most economically be constructed of deck girders, investigation showed that a considerable saving could be effected by the use of a single span vertical lift bridge.

Had a swing span been adopted it is probable that the Department would have insisted upon a larger opening to compensate for the greater difficulty that boats would experience in getting by the extended arms of the draw when opened.

The cost figures that led to the adoption of the vertical lift span are as follows:

VERTICAL LIFT BRIDGE.

1-162 ft. through riveted truss	$ 20,000
Towers	5,000
All apparatus for raising, including counterweights	15,000
2 rest piers	50,000
12-75-ft. deck-plate girder approach spans	24,000
12 deck girder rest piers	84,000
Trestle approach	2,000
Grand total for Vertical Lift Bridge	$200,000

SWING BRIDGE.

1-350-ft. swing drawspan	$ 38,000
Operator's house and machinery	17,000
1 swing draw pivot pier	31,000
2 draw rest piers	42,000
10-75-ft. deck-plate girder spans	20,000
10 deck girder rest piers	70,000
Trestle approach	2,000
Grand total for Swing Bridge	$220,000

(Both of above estimates include transportation at full tariff rates.)

The St. Francis River does not have a swift current, the channel changes very little, nor is there much scour of the river bed, which is composed of sand and gravel overlying blue clay. These conditions caused the decision to use pile foundations, penetration of 35 ft. to 40 ft. being secured below the bottom of the footings by the aid of two 2-in. water jets.

Steel sheet piles were used for the cofferdams of two piers, but considerable difficulty was experienced in pumping them out. Timber cribs were used for all the remaining piers. These cribs were framed on shore or barges, launched and lowered into place. When in place they were built up to the desired height and platforms built on top of them for loading purposes. The excavations within the cribs were made by clam shell or orange peel dredges, the weight for sinking the cribs being provided by dumping excavated material onto the loading platforms. The excavation was usually carried two or three feet below the desired bottom of footing before pile driving commenced.

Piles were then driven to the required depth, the piles having been purchased long enough so that at low water stages it was not necessary to follow them through the water, the required penetration being obtained by driving the piles down until their tops reached the water surface. The practical refusal of the pile to go down under further driving, however, and not an arbitrary depth of penetration, was the

condition that had to be met. When it was considered desirable to drive piles during any high stage of the water they were started down without jetting and penetrations of 20 ft. to 30 ft. were secured with a No. 2 Vulcan steam hammer. When the piles refused to go further or the tops reached the water surface they were left to be followed down later. A second driver equipped with a follower and two 2-in. water jets then drove the piles further, usually sending the tops 10 ft. or 15 ft. under water until the desired penetration was secured.

On account of the porous nature of the river bed no attempt was made to pump out any cofferdams until concrete was placed. Immediately upon the completion of the driving the sand that had been brought up by the jets was removed down to the required depth by a water ejector (known on the work as a "sand sucker"). The sealing course of 1:2:3 concrete was then placed through a 10-in. steel pipe tremie, which was very carefully and thoroughly moved around among the pile heads, the concrete being placed from three to five feet deep. When this concrete had set four or five days the cofferdam was pumped out, piles cut off, and pier completed. All concrete placed under water was placed very wet.

At a few piers in the deep water the defective construction of the cofferdams made it impossible to pump them out. They were constructed of 10 in. x 10 in. gum timbers, laid horizontally, breaking joints, lapped at the corners and each course drifted to the course below by ¾-in. round drift bolts every three feet. The timber was not surfaced and the openings were stopped by driving shingles between the timbers. It would have been preferable to have sheeted the cofferdams, but had the calking with shingles been well done very little trouble would have been experienced. Hot weather, accompanied by frequent heavy rains, in a construction camp in the lowlands of Arkansas, with its accompanying illness, is not conducive to man's best efforts, however, and consequently the cofferdams were not built as well as they could have been built.

Where a cofferdam could not be pumped out after the sealing concrete had been placed it was decided to cut off the pile heads close to the top of the sealing course by means of a circular saw operated by a vertical shaft, place the remainder of the footing course under water by means of a bottom dump bucket and, if considered advisable, make a further effort to pump out the crib. If this second attempt were not successful or not attempted, special form for the lower section of the pier shaft was constructed for lowering down onto the footing. In one case this special form was built out on the river bank, floated out to the cofferdam when water was several feet over its top and lowered onto the top of the footing course. In another case the form was built on supports resting on top of the crib and was lowered by block and falls. Efforts were made to lower this form before the concrete in the footing course had set. When the form rested on the footing

about 12 in. of concrete was placed through a tremie between the outside of the form and the inside of the cofferdam to prevent cement from running out of the concrete to be placed in the forms. Several feet of concrete was then placed within the form by a bottom dump bucket, and allowed to set, after which the form was pumped out and the construction of the pier proceeded with.

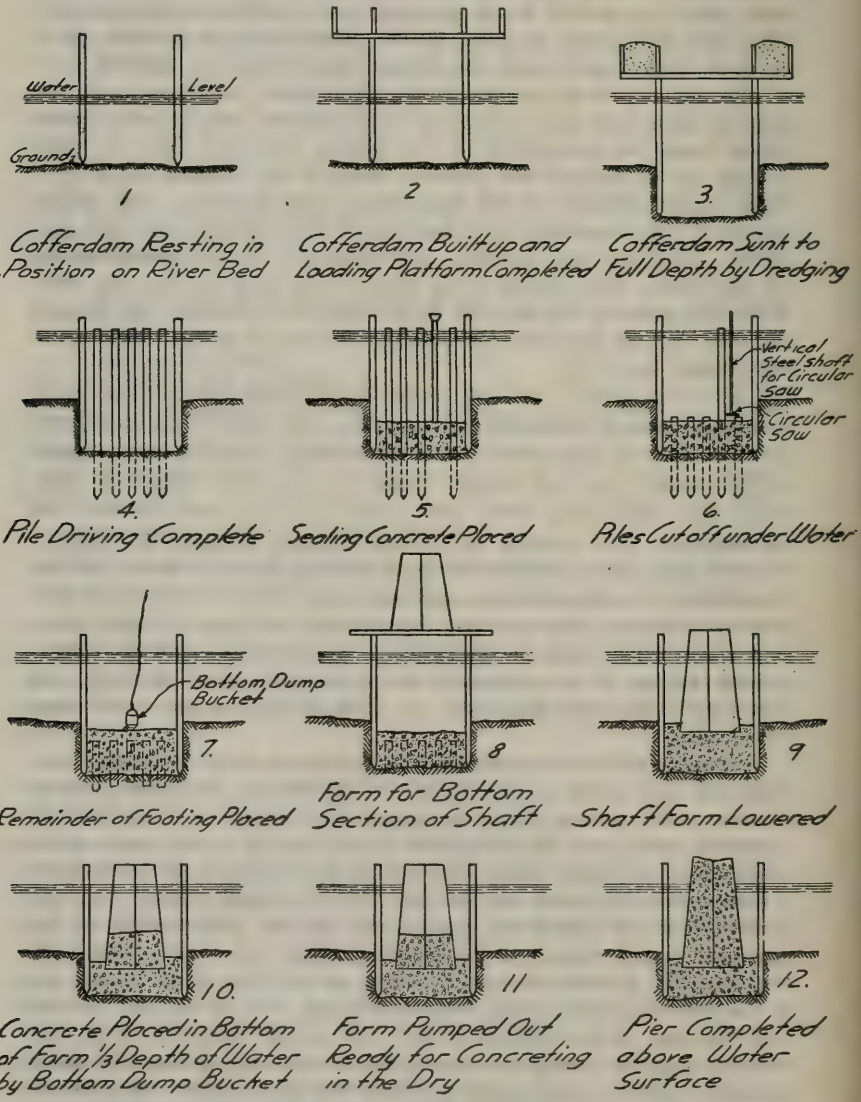


FIG. 28—ST. FRANCIS RIVER BRIDGE, SKETCHES SHOWING METHOD OF CONSTRUCTION OF CONCRETE PIERS WHEN CONDITIONS PREVENT COFFERDAMS BEING PUMPED OUT.

Before placing new concrete on former concrete placed under water, the laitance, sediment and other accumulated material was washed from the top of the lower concrete and removed by the sand sucker. Sometimes an entire day would be spent in this cleaning process, especially when pile heads projected above the concrete; the cleaning was continued until the sounding rod showed hard concrete over the entire area.

The water level in the St. Francis River at the point of crossing is greatly affected by the stage of the Mississippi River; the level changed so often that the work was greatly delayed.

At the time the contract for the substructure was let the water in the river was very low and no track had been laid. On account of the low stage of the river which gave only 8 in. to 10 in. depth of water over a number of long bars it was practically impossible to get the plant to the bridge by boat, so it was hauled ten miles from the nearest railroad station through swamps that could be hauled over only in dry periods. Frequent rains rendered such roads as were there impassable and seriously delayed the assembling of the contractor's plant and camp equipment. Cofferdam lumber and lumber for barges was brought from mills on the river and floated to the bridge. By constant dredging and dragging some of the bars it was possible to handle a small amount of material from a point on a railroad about forty miles up the river. There were plenty of good foundation piles standing in the swamps near the location of the bridge, but the prices asked for them were so high that it was more economical to purchase them elsewhere. They were shipped to the unloading point up the river, unloaded into the river there and floated down. The difficulty in getting plant and material to the bridge seriously delayed the commencement of the work. When track reached the bridge practically the entire plant, cofferdam material and piling had been delivered at the bridge and work was well under way. The principal aid given by the track was in the delivery of cement and gravel and form materials.

Extreme low water stage was never reached during the construction of the bridge. The lowest water was experienced during the commencement of the work, when it was impossible to take advantage of it on account of insufficient plant and materials. It was also during the hot months, and there were frequent rains, which made it difficult to secure sufficient men.

Track reached the bridge at the beginning of cool weather, but there followed a spell of high water that stopped the work. Then came a spell of comparatively low water, during which a great deal of work was done, and then came the beginning of the spring flood of 1912 that has caused such unprecedented damage in the lower Mississippi Valley, the latter flood effectually stopping all work at the bridge for several months.

When the letter of invitation for the substructure work was being prepared it was realized that it would be impossible for any Contractor to estimate the cost of transportation before track reached the bridge;

consequently the cost of transporting materials and equipment to the bridge was placed on a force account basis. The remainder of the foundation work was on a unit price basis. This method of payment proved entirely satisfactory to all concerned.

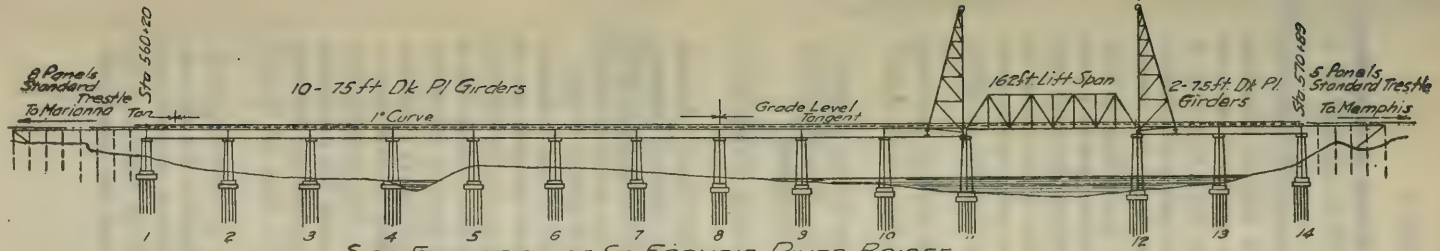
It is the intention to place the approach girders with a derrick car without falsework. For the lift span, pile bents will be driven, and frame bents placed on top of them. This span will be riveted up complete as a simple span and the falsework removed before proceeding with the erection of the towers. The end from which the erection of the lift span and towers will be handled depends somewhat on the progress of track laying east of the bridge, which has been delayed on account of excessive rains. If track reaches the bridge in time erection will commence from the east end and boats will be required to pass between piers 9 and 10 while the channel is blocked, a temporary channel being dredged if necessary. If erection commences from the west end the span between piers 9 and 10 will be installed as a temporary lift span and provided with towers and counterweights.

The contract for erection includes a fixed sum (about $350) for installing and dismantling the temporary lifting apparatus and a unit price (about $5) to be paid the contractor for each opening of the temporary lift span to permit boats to pass.

When the great spring flood of 1912 started there was about thirty days' work required to bring all the piers above ordinary water level, after which they could have been brought up as the water rose. On this basis the erection contractor was instructed to have his equipment at the bridge during February; it arrived the same day the rise started and after he unloaded the steelwork he was permitted to ship his equipment away.

If the stage of water during erection is such that large boats and tows use the river it will be necessary to make special arrangements to get them through the narrow opening of approximately 55 ft. clear width between piers 9 and 10. This width is sufficient to permit any single boat to pass through, but will not accommodate them when lashed abreast. It is proposed to assist boats with tows by the use of the tow boat formerly used for transporting materials to the bridge. When tows arrive the barges will be taken through the opening singly and anchored on the other side, after which the steamer will pass through, pick up the barges and proceed.

The 12-75-ft. deck plate girder spans weigh about 450 tons. The lift span is a 162-ft. single track through riveted truss span, practically a duplicate of a simple span used in another bridge, slight alterations having been made to provide for the necessary attachments. The alterations to the former plans and the details of the towers and lifting mechanism were worked out by Waddell and Harrington, Consulting Engineers of Kansas City, who control the patents of the type of lift bridge used at this point. The lift span with all attachments for machinery comprised 250 tons of



SIDE ELEVATION OF ST FRANCIS RIVER BRIDGE

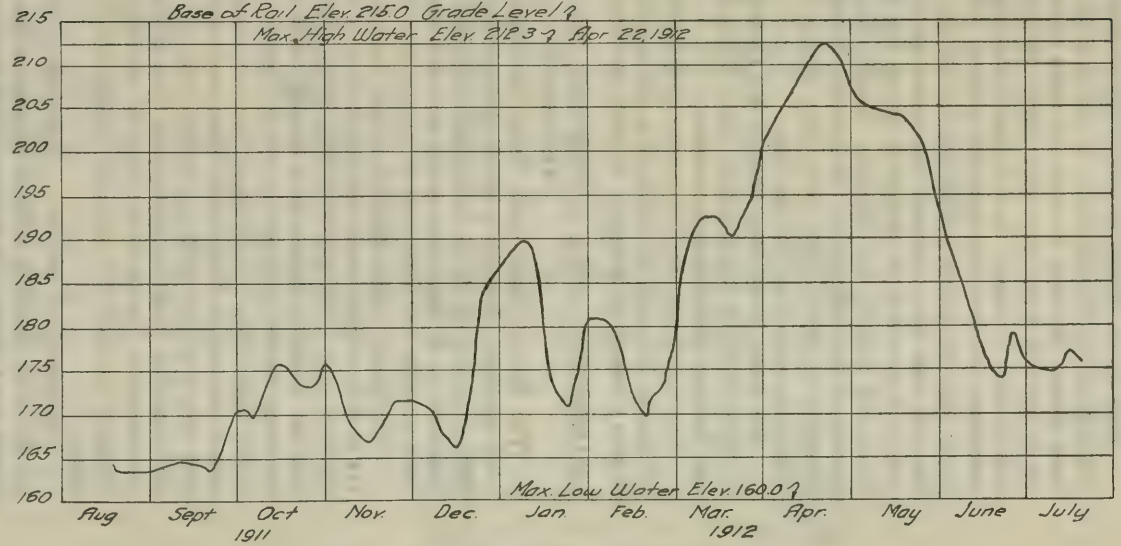


FIG. 29—HYDROGRAPH OF ST. FRANCIS RIVER.

structural steel, the towers 140 tons, counterweight frames 10 tons, machinery 40 tons, and 7 tons of cables. The span will be operated by a 25-horsepower gasoline engine. Total lift, 70 ft.

Prior to the design of this bridge it was the practice to attach the tail legs of the lifting towers to masonry or to the hips of adjoining truss spans. In order to avoid the extra expense of additional supports or of approach truss spans that would otherwise have been necessary, it was decided to support the tail legs of the towers on cantilever brackets extending out from the approach girders. The load from the vertical tower legs, the counterweight and the lift span are transmitted directly into the main pier; the load that comes on the cantilever brackets consists of a portion of the weight of the tail legs and bracing and some load from wind pressure and vibration. Should the vibration of the towers on account of the deflection of the approach girder spans under traffic prove excessive or objectionable extra deck girders can be installed to afford additional support for the tail legs.

The entire bridge was designed for Cooper's E-50 loading according to Missouri Pacific specifications, which conform with those of the American Railway Engineering Association.

The foundation work was done by the Kansas City Bridge Company of Kansas City and the fabrication and erection by the Virginia Bridge & Iron Company of Roanoke, Virginia, and Memphis, Tennessee.

DRAWBRIDGE OVER LITTLE RED RIVER NEAR JUDSONIA, ARKANSAS.

The former single track bridge consisting of one 113-ft. through truss approach span and a 260-ft. through truss draw span on masonry piers was replaced on the same center line by a 260-ft. double track draw span and 113-ft. deck plate girder approach spans on the old piers, which were extended and reinforced to support the wider and heavier bridge.

The former bridge afforded a clear channel opening of approximately 114 ft. 6 in. at high water and 109 ft. 6 in. at low water on each side of the pivot pier. This was more than ample, partly on account of the fact that the bridge is located in a straight reach of the river, which has a moderate current, and because the navigation of the river at this point is very light, being entirely absent at some periods and at others consisting almost entirely of Government boats and barges plying to and from a rock quarry a few miles up stream from the bridge. No trouble was experienced in obtaining permission from the Government for narrowing the channel to 108 ft. at all stages of water, which enabled the Railway Company to place the necessary reinforcement on the sides of the old piers.

Enlargement of the piers and abutments consisted in extending them up and down stream a sufficient distance to provide supports for the new double track bridge; in addition a thin shell of reinforced concrete was placed on each side of each pier and on the faces of the abutments for the purpose of connecting the extensions. This made the pivot pier

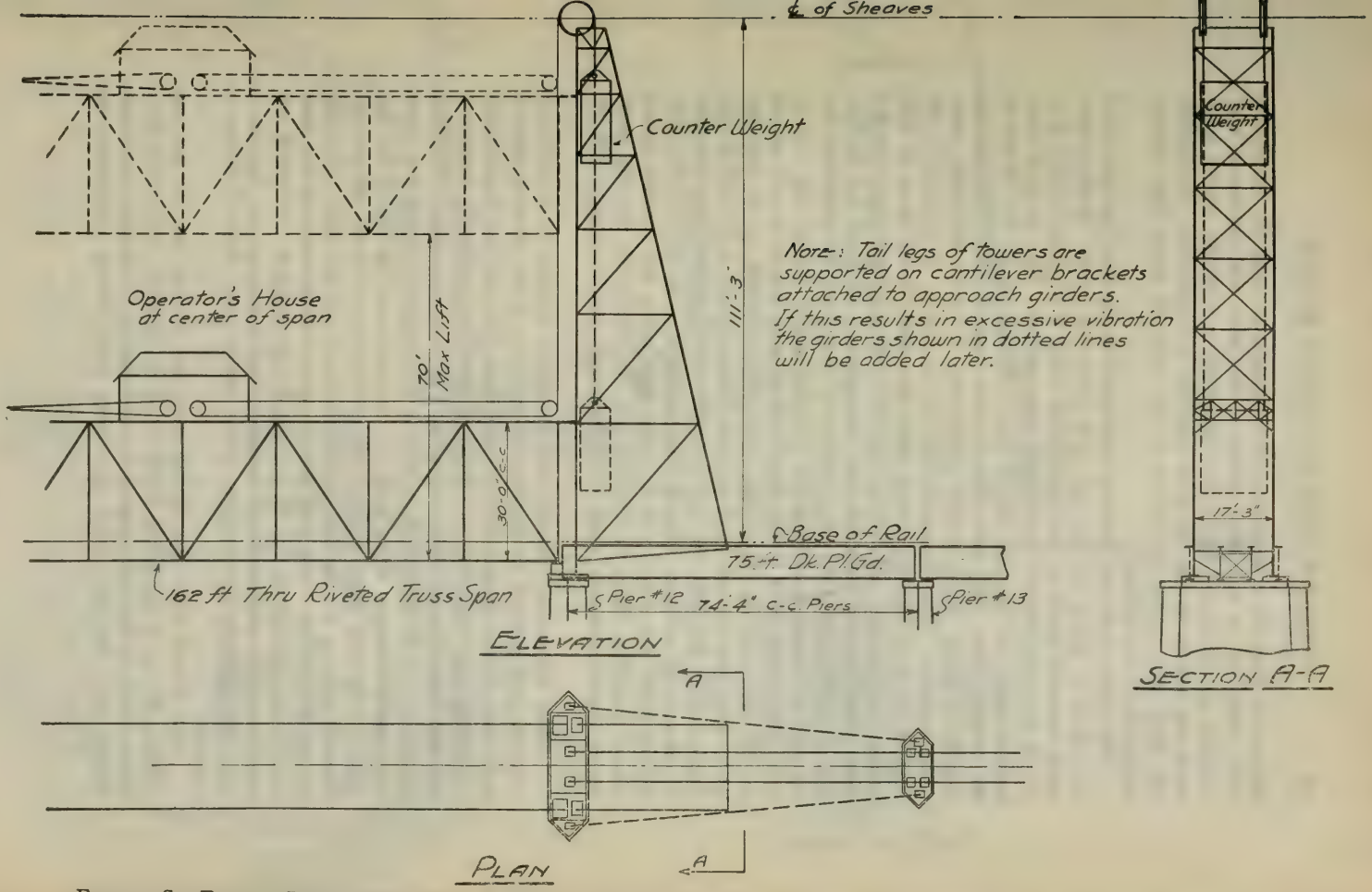


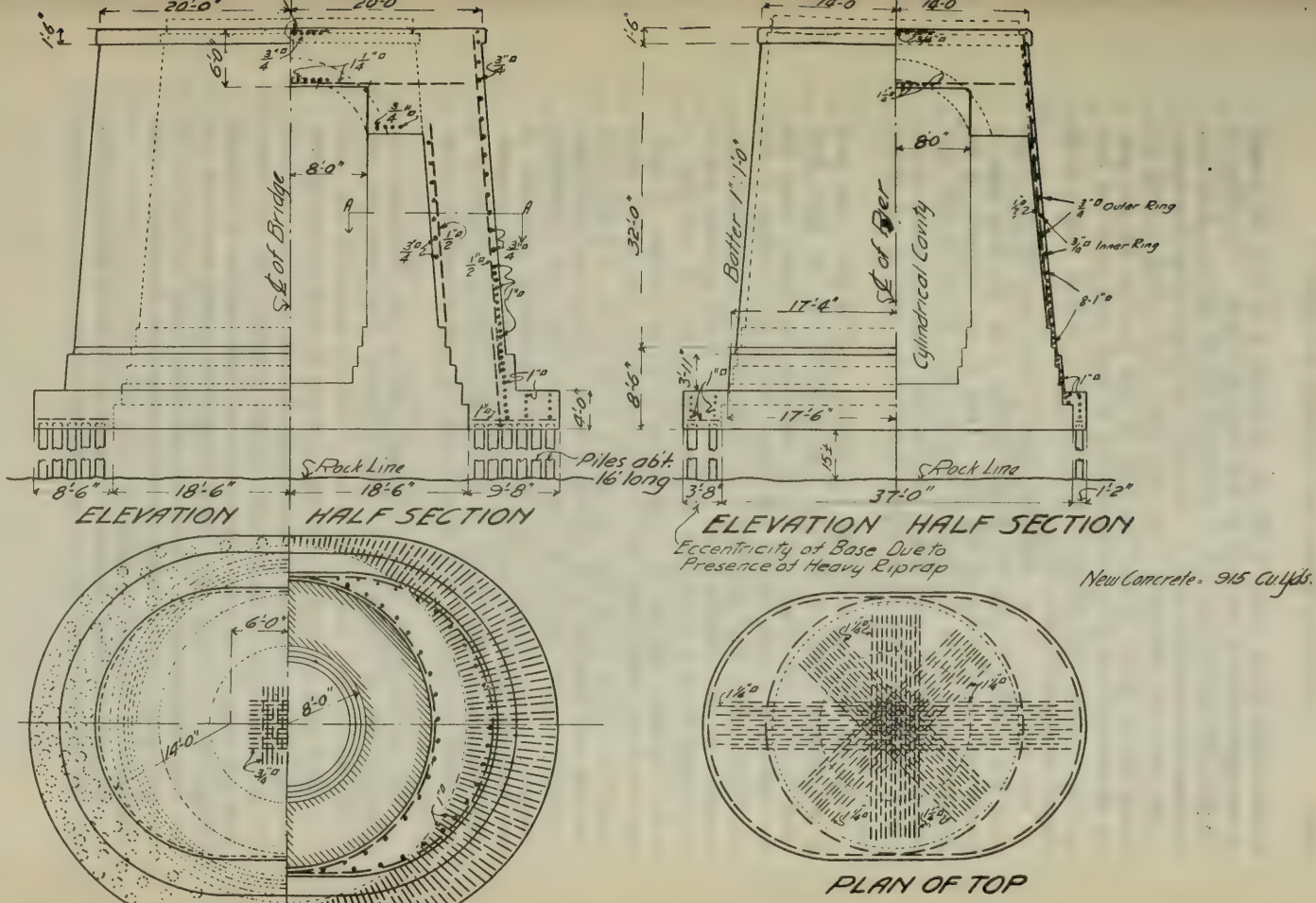
FIG. 30—ST. FRANCIS RIVER BRIDGE, SKETCH SHOWING ARRANGEMENT OF TOWERS, COUNTERWEIGHTS AND LIFTING MECHANISM.

elliptical in plan, the coping being 28 ft. measured along the bridge and 40 ft. measured up and down stream. The piers and abutments were enlarged and reinforced up to the bridge seats without the use of falsework and without placing the draw span out of commission. Fortunately this work was carried out during a low stage of water that reduced navigation to a minimum.

The plans of the old masonry indicated that the pier footings rested on rock 51 ft. below the rail and 15 ft. below low water. Borings indicated cemented gravel at that level, below which 6 ft. of gravel and 9 ft. of silt were encountered before rock was reached. The result of these borings led to the idea that the old piers extended deeper than shown on the original plans and either rested upon rock or were supported on foundation piling. Both of these assumptions, however, were later found to be incorrect. The increased depth of rock led to an increase in the sizes of the new footings. Steel sheet piles were driven down to rock around the pivot pier and the material within the cofferdam was excavated down to the bottom of the old pier. Investigation disclosed that the bottom of footing was at the elevation shown on the original plans, but that the footings rested directly on the cemented gravel without pile foundation. Foundation piles to the number of 88 were driven to rock around the old piers and the entire area within the cofferdam, 42 ft. wide and 55 ft. long, was covered by a concrete footing course 4 ft. thick heavily reinforced to distribute the load as uniformly as possible over the piles. To prevent the concrete footing from floating around and into the interlocking heads and grooves of the steel sheet piling and thereby causing trouble in pulling them, the concrete was separated from the steel sheeting by boards one inch thick laid horizontally and in contact with the grooves.

Above the footing the pier was completely enclosed in a reinforced concrete shell varying in thickness from 9 in. on the channel sides to 6 ft. 9 in. on the up and down stream ends. The up and down stream extensions were necessary to provide support for the center wedges of the new draw trusses, which are 30 ft. 4 in. center to center. The shell was reinforced by horizontal reinforcing rods one inch square 9 in. apart near the bottom and ¾ in. square 14 in. apart near the top of the pier. One-half the bars passed around close to the surface of the old pier and one-half close to the surface of the reinforced concrete shell. The shell on the channel sides was made thin to avoid encroachment on the channels; it was particularly for the purpose of embedding the horizontal rods that joined the extensions of the piers, but it also gives the pier a uniform appearance, inasmuch as the entire stone work is buried in concrete.

The former draw span having been rim bearing, the old pier was hollow, having a cylindrical cavity 16 ft. in diameter surmounted by a dome, which in turn was covered by solid masonry, forming a continuous bridge seat. The new draw span being pivot bearing necessitated the


20'-0"
20'-0"
8'-0"
℄ of Bridge
℄ Rock Line
Piles abt. 16' long
8'-6"
18'-6"
18'-6"
9'-8"
ELEVATION
HALF SECTION
14'-0"
14'-0"
32'-0"
Batter 1":10"
℄ of Pier
Cylindrical Cavity
8'-0"
17'-4"
17'-6"
8'-6"
3'-0" Outer Ring
3'-0" Inner Ring
8'-1"
℄ Rock Line
3'-8"
37'-0"
1'-2"
ELEVATION HALF SECTION
Eccentricity of Base Due to Presence of Heavy Riprap
New Concrete - 915 Cu Yds.
6'-0"
8'-0"
14'-0"
PLAN
HALF SECTION A-A
PLAN OF TOP

reconstruction of the center of the pier to enable it to carry the weight of the span and such live load as will reach the center. The filling of the pier with solid concrete was contemplated, but the idea was abandoned as it was desired to avoid such an increase in the weight on the foundation, consequently the old masonry was torn down 12 ft., which entirely removed the old dome. It was then built up with concrete, the slab over the 16-ft. cylindrical cavity being made 6 ft. thick and reinforced with 44 1¼-in. square bars placed in four sets of 11 each at angles of 45 degrees each with the next set.

The steel work of the new draw span is wider than the top of the pivot pier measured along the bridge, so that when the draw span is turned the trusses overhang the pier. They do not encroach on the channel more than the pier, however, as the sides of the old pier were battered to such an extent that a vertical line from the outside of the steel work when turned at 90 degrees intersects the battered side of the pier at about low water line.

Approximately 1,000 cu. yds. of concrete and 88 piles were used in the reconstruction of this pier. It supported the old draw span ready for turning during the entire reconstruction except when the top was being rebuilt, which was done during the erection of the steel work. If a new pier had been constructed it would have been necessary to have removed about 1,000 cu. yds. of old masonry and to have placed about 2,500 cu. yds. of new concrete and 250 new piles or to have increased the cost by going to rock with the footing. In addition the bridge would have been on falsework for a long period, which would have added to the cost and hazard of the work. If a new pivot pier had been proposed it is probable that the Government would have demanded a wider channel, as the War Department was undoubtedly influenced in its approval of the plans by the reasonable contraction of the channel asked for by the Railway Company and by the comparatively slight expense at which the foundations could be adjusted to a new double track bridge as compared with the cost of complete reconstruction.

The reconstruction of the rest pier and of the abutments was similar to that of the pivot pier. The reinforced shell along the sides of the old rest pier and on the faces of the old abutments was made 9 in. thick and anchored to the old masonry by ½-in. square anchor rods placed 5 ft. center to center in each direction. The extensions of the pier and of the abutments were placed on piles. The end extensions are about 8 ft. long. The new steel work required a different arrangement of bridge seats, which necessitated cutting down the old rest piers and abutments. This work was done during the erection of the steel work and the entire length of bridge seat was built in one operation and heavily reinforced.

In order to avoid the heavy expense of building gravity wings for the abutments on piling it was decided to continue the abutments

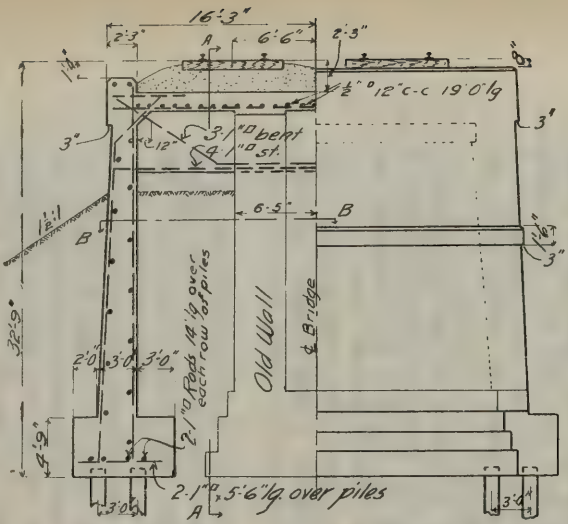
as "U" shaped structures. For this purpose new tail walls were built parallel with the track outside of the old abutments. The tail walls rest on footings 8 ft. wide at the base and 5 ft. deep. The tail walls were made 3 ft. thick at the bottom and 2 ft. thick at the top and heavily reinforced with ¾-in. square bars 12 in. to 18 in. center to center. A reinforced concrete slab 18 in. thick was then built for the support of the ballast and track, this slab extending back about 20 ft. from the back wall. The slab rests on four supports, two of which on the outside are provided by the new reinforced tail walls and two on the inside are provided by the old masonry tail walls.

The specifications for erection provided that the expense of caring for navigation would be borne by the Railway Company. Amicable arrangements were made with the Government to close the channel with the exception of a 50-ft. opening which was provided in the falsework by the use of a second hand deck plate girder span, which opening was large enough to permit the passage of the stone barges used by the Government, but would not permit the passage of their steam towboat. The Railway Company hired a small towboat to assist the Government in getting the barges to and from the rock quarry. The Railway Company's towboat handled the empty barges from the bridge up stream to the quarry and handled the barges loaded with rock from the quarry down stream to the bridge. The Government towboat handled the empties to the bridge and took the loaded barges away. The arrangement proved to be entirely satisfactory. The deck plate girders in the approach span were placed one at a time on falsework after the old through truss span had been taken down and for a time track was supported on the two inside girders, as it was necessary to maintain single track across the bridge in its old location for some time after the completion of the erection.

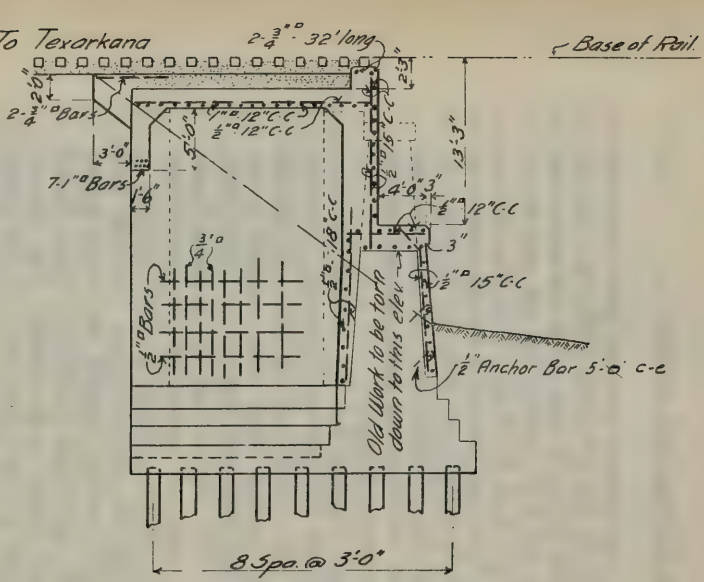
In order to avoid the possibility of getting the line cut in two in case of flood the new draw trusses were erected complete on falsework outside of the old bridge before the old structure was dismantled and the old trusses were then taken down inside of the new trusses.

The draw span is a 12-panel riveted disc center-bearing swing span of ordinary construction operated by a 40-horsepower Fairbanks-Morse gasoline engine in a reinforced concrete house over the center pier.

The bridge was designed for Cooper's E-50 loading according to the specifications of the Missouri Pacific Railway Company, which conform with those of the American Railway Engineering Association. The weight of structural steel in the two 113 ft. deck-plate girder spans amounts to 175 tons and in the draw span 620 tons, and of the machinery 75 tons. The total cost of the bridge amounted to about $125,000. Substructure work and steel erection were performed by the Kansas City Bridge Company of Kansas City, Mo., and the steel work was fabricated by the Virginia Bridge & Iron Company of Roanoke, Va., and Memphis, Tenn.

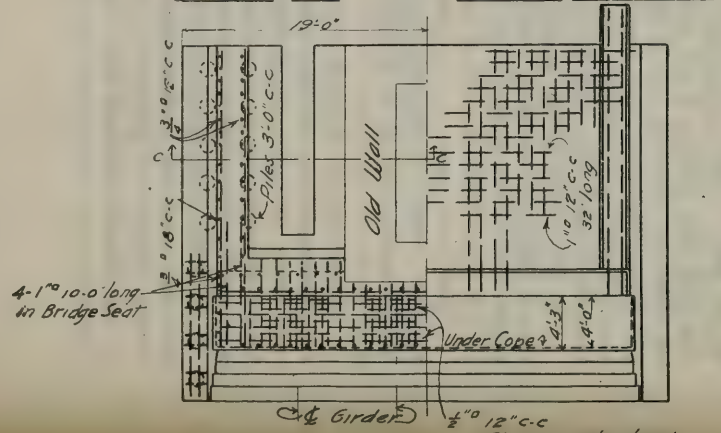


SECTION C-C



SECTION A-A

½ FRONT ELEVATION



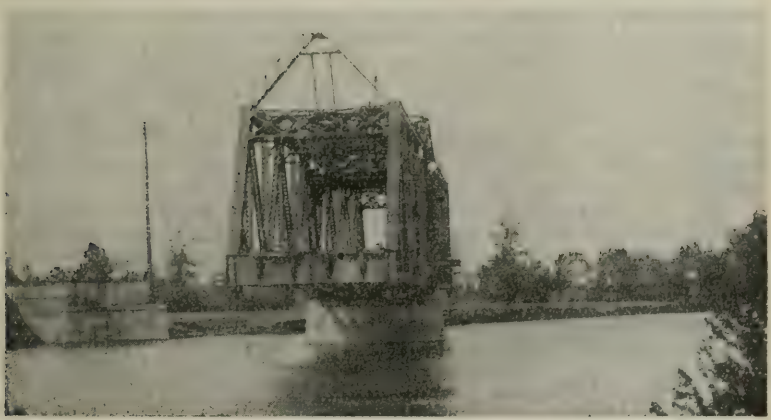
½ SECTIONAL PLAN B-B

HALF PLAN

FIG. 33—LITTLE RED RIVER DRAWBRIDGE DURING WORK ON PIERS AND BEFORE COMMENCEMENT OF WORK ON SPANS.

Fig. 34—Little Red River Drawbridge During Erection of Draw Span. Old Single-track Draw Span Can Be Seen Inside of New Double Track Span at Left. Old Span Entirely Removed in Picture at Right.

Draw Span Closed.



Draw Span Open.

FIG. 35- LITTLE RED RIVER DRAWBRIDGE AFTER COMPLETION.

CHAP. 1130. AN ACT TO REGULATE THE CONSTRUCTION OF BRIDGES OVER NAVIGABLE WATERS.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, that when hereafter authority is granted by Congress to any persons to construct and maintain a bridge across or over any of the navigable waters of the United States, such bridge shall not be built or commenced until the plans and specifications for its construction, together with such drawings of the proposed construction and such map of the proposed location as may be required for a full understanding of the subject, have been submitted to the Secretary of War and Chief of Engineers for their approval, nor until they shall have approved such plans and specifications and the locations of such bridge and accessory works; and when the plans for any bridge to be constructed under the provisions of this Act have been approved by the Chief of Engineers and by the Secretary of War it shall not be lawful to deviate from such plans, either before or after completion of the structure, unless the modification of such plans has previously been submitted to and received the approval of the Chief of Engineers and of the Secretary of War.

Sec. 2. That any bridge built in accordance with the provisions of this Act shall be a lawful structure and shall be recognized and known as a post route, upon which no higher charge shall be made for the transmission over the same of the mails, the troops and the munitions of war of the United States than the rate per mile paid for the transportation over any railroad, street railway, or public highway leading to said bridge; and the United States shall have the right to construct, maintain and repair, without any charge therefor, telegraph and telephone lines across and upon said bridge and its approaches; and equal privileges in the use of said bridge and its approaches shall be granted to all telegraph and telephone companies.

Sec. 3. That all railroad companies desiring the use of any railroad bridge built in accordance with the provisions of this Act shall be entitled to equal rights and privileges relative to the passage of railway trains or cars over the same and over the approaches thereto upon payment of a reasonable compensation for such use; and in case of any disagreement between the parties in regard to the terms of such use or the sums to be paid all matters at issue shall be determined by the Secretary of War upon hearing the allegations and proofs submitted to him.

Sec. 4. That no bridge erected or maintained under the provisions of this Act shall at any time unreasonably obstruct the free navigation of the waters over which it is constructed, and if any bridge erected in accordance with the provisions of this Act shall, in the opinion of the Secretary of War, at any time unreasonably obstruct such navigation, either on account of insufficient height, width of span, or otherwise, or if there be difficulty in passing the draw opening or the drawspan of such bridge by rafts, steamboats, or other water craft, if shall be the duty of the Secretary of War, after giving the parties interested reasonable opportunity to be heard, to notify the persons owning or controlling such bridge to so alter the same as to render navigation through or under reasonably free, easy, and unobstructed, stating in such notice the changes required to be made, and prescribing in each case a reasonable time in which to make such changes, and if at the end of the time so specified the changes so required have not been made, the persons owning or controlling such bridge shall be deemed guilty of a violation of this Act; and all such alterations shall be made and all such obstructions shall be removed at the expense of the persons owning or operating said bridge. The persons owning or operating any such bridge shall

maintain, at their own expense, such lights and other signals thereon as the Secretary of Commerce and Labor shall prescribe. If the bridge shall be constructed with a draw, then the draw shall be opened promptly by the persons owning or operating such bridge upon reasonable signal for the passage of boats and other water craft. If tolls shall be charged for the transit over any bridge constructed under the provisions of this Act, of engines, cars, street cars, wagons, carriages, vehicles, animals, foot passengers, or other passengers, such tolls shall be reasonable and just, and the Secretary of War may, at any time, and from time to time prescribe the reasonable rates of toll for such transit over such bridge, and the rates so prescribed shall be the legal rates and shall be the rates demanded and received for such transit.

Sec. 5. That any persons who shall fail or refuse to comply with the lawful order of the Secretary of War or the Chief of Engineers, made in accordance with the provisions of this Act, shall be deemed guilty of a violation of this Act, and any person who shall be guilty of a violation of this Act shall be deemed guilty of misdemeanor, and on conviction thereof shall be punished in any court of competent jurisdiction by a fine not exceeding $5,000, and every month such person shall remain in default shall be deemed a new offense and subject such persons to additional penalties therefor; and in addition to the penalties above described the Secretary of War and the Chief of Engineers may, upon refusal of the persons owning or controlling any such bridge and accessory works to comply with any lawful order issued by the Secretary of War or Chief of Engineers in regard thereto, cause the removal of such bridge and accessory works at the expense of the persons owning or controlling such bridge, and suit for such expense may be brought in the name of the United States against such persons, and recovery had for such expense in any court of competent jurisdiction; and the removal of any structures erected or maintained in violation of the provisions of this Act or the order or direction of the Secretary of War or Chief of Engineers made in pursuance thereof may be enforced by injunction, mandamus, or other summary process, upon application to the circuit court in the district in which such structure may, in whole or in part, exist, and proper proceedings to this end may be instituted under the direction of the Attorney-General of the United States at the request of the Secretary of War; and in case of any litigation arising from any obstruction or alleged obstruction to navigation created by the construction of any bridge under this Act, the cause or question arising may be tried before the circuit court of the United States in any district which any portion of said obstruction or bridge touches.

Sec. 6. That whenever Congress shall hereafter by law authorize the construction of any bridge over or across any of the navigable waters of the United States, and no time for the commencement and completion of such bridge is named in said Act, the authority thereby granted shall cease and be null and void unless the actual construction of the bridge authorized in such Act be commenced within one year and completed within three years from the date of the passage of such Act, unless by further consent of Congress.

Sec. 7. That the word "persons" as used in this Act shall be construed to import both the singular and the plural, as the case demands, and shall include municipalities, quasi municipal corporations, corporations, companies and associations.

Sec. 8. That the right to alter, amend, or repeal this Act is hereby expressly reserved as to any and all bridges which may be built in accordance with the provisions of this Act, and the United States shall incur no liability for the alteration, amendment, or repeal thereof to the owner or owners or any other persons interested in any bridge which shall have been constructed in accordance with its provisions.

Appendix B.

LAWS FOR THE PROTECTION AND PRESERVATION OF THE NAVIGABLE WATERS OF THE UNITED STATES.

EXTRACT FROM THE RIVER AND HARBOR ACT APPROVED MARCH 3, 1899.

Construction of bridges, consent of Congress necessary for.

SEC. 9. That it shall not be lawful to construct or commence the construction of any bridge, dam, dike, or causeway over or in any port, roadstead, haven, harbor, canal, navigable river, or other navigable water of the United States until the consent of Congress to the building of such structures shall have been obtained and until the plans for the same shall have been submitted to and approved by the Chief of Engineers and by the Secretary of War: *Provided,* That such structures may be built under authority of the legislature of a State across rivers and other waterways the navigable portions of which lie wholly within the limits of a single State, provided the location and plans thereof are submitted to and approved by the Chief of Engineers and by the Secretary of War before construction is commenced: *And provided further,* That when plans for any bridge or other structure have been approved by the Chief of Engineers and by the Secretary of War, it shall not be lawful to deviate from such plans either before or after completion of the structure unless the modification of said plans has previously been submitted to and received the approval of the Chief of Engineers and of the Secretary of War.

Creation of obstructions forbidden.

SEC. 10. That the creation of any obstruction not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States, is hereby prohibited; and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty, or other structures in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and it shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of, any port, roadstead, haven, harbor, canal, lake harbor of refuge, or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same.

Harbor lines, establishment of.

SEC. 11. That where it is made manifest to the Secretary of War that the establishment of harbor lines is essential to the preservation and protection of harbors he may, and is hereby, authorized to cause such lines to be established, beyond which no piers, wharves, bulkheads, or other works shall be extended or deposits made, except under such regulations as may be prescribed from time to time by him: *Provided,* That whenever the Secretary of War grants to any person or persons permission to extend piers, wharves, bulkheads, or other works, or to

make deposits in any tidal harbor or river of the United States beyond any harbor lines established under authority of the United States, he shall cause to be ascertained the amount of tide water displaced by any such structure or by any such deposits, and he shall, if he deem it necessary, require the parties to whom the permission is given to make compensation for such displacement either by excavating in some part of the harbor, including tide-water channels between high and low water mark, to such an extent as to create a basin for as much tide water as may be displaced by such structure or by such deposits, or in any other mode that may be satisfactory to him.

Penalties for violations of three preceding sections.

SEC. 12. That every person and every corporation that shall violate any of the provisions of sections 9, 10 and 11 of this Act, or any rule or regulation made by the Secretary of War in pursuance of the provisions of the said section 11, shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding twenty-five hundred dollars nor less than five hundred dollars, or by imprisonment (in the case of a natural person) not exceeding one year, or by both such punishments, in the discretion of the court. And further, the removal of any structures or parts of structures erected in violation of the provisions of the said sections may be enforced by the injunction of any circuit court exercising jurisdiction in any district in which such structures may exist, and proper proceedings to this end may be instituted under the direction of the Attorney-General of the United States.

SEC. 13. That it shall not be lawful to throw, discharge, or deposit, or cause, suffer, or procure to be thrown, discharged, or deposited either from or out of any ship, barge, or other floating craft of any kind, or from the shore, wharf, manufacturing establishment, or mill of any kind, any refuse matter of any kind or description whatever other than that flowing from streets and sewers and passing therefrom in a liquid state, into any navigable water of the United States, or into any tributary of any navigable water from which the same shall float or be washed into such navigable water; and it shall not be lawful to deposit, or cause, suffer, or procure to be deposited, material of any kind in any place on the bank of any navigable water, or on the bank of any tributary of any navigable water, where the same shall be liable to be washed into such navigable water, either by ordinary or high tides, or by storms or floods, or otherwise, whereby navigation shall or may be impeded or obstructed: *Provided,* That nothing herein contained shall extend to, apply to, or prohibit the operations in connection with the improvement of navigable waters or construction of public works, considered necessary and proper by the United States officers supervising such improvement or public work: *And provided further,* That the Secretary of War, whenever in the judgment of the Chief of Engineers anchorage and navigation will not be injured thereby, may permit the deposit of any material above mentioned in navigable waters, within limits to be defined and under conditions to be prescribed by him, provided application is made to him prior to depositing such material; and whenever any permit is so granted the conditions thereof shall be strictly complied with, and any violation thereof shall be unlawful.

Injuries to Government works, etc., in navigable waters.

SEC. 14. That it shall not be lawful for any person or persons to take possession of or make use of for any purpose, or build upon, alter, deface, destroy, move, injure, obstruct by fastening vessels thereto or otherwise, or in any manner whatever impair the usefulness of any sea wall, bulkhead, jetty, dike, levee, wharf, pier, or other work built by the United States, or any piece of plant, floating or otherwise, used in the

construction of such work under the control of the United States, in whole or in part, for the preservation and improvement of any of its navigable waters or to prevent floods, or as boundary marks, tide gages, surveying stations, buoys, or other established marks, nor remove for ballast or other purposes any stone or other material composing such works: *Provided*, That the Secretary of War may, on the recommendation of the Chief of Engineers, grant permission for the temporary occupation or use of any of the aforementioned public works when in his judgment such occupation or use will not be injurious to the public interest.

Anchoring or sinking of vessels in navigable channels forbidden.

SEC. 15. That it shall not be lawful to tie up or anchor vessels or other craft in navigable channels in such a manner as to prevent or obstruct the passage of other vessels or craft; or to voluntarily or carelessly sink, or permit or cause to be sunk, vessels or other craft in navigable channels; or to float loose timber and logs, or to float what is known as sack rafts of timber and logs in streams or channels actually navigated by steamboats in such manner as to obstruct, impede, or endanger navigation. And whenever a vessel, raft, or other craft is wrecked and sunk in a navigable channel, accidentally or otherwise, it shall be the duty of the owner of such sunken craft to immediately mark it with a buoy or beacon during the day and a lighted lantern at night, and to maintain such marks until the sunken craft is removed or abandoned, and the neglect or failure of the said owner so to do shall be unlawful; and it shall be the duty of the owner of such sunken craft to commence the immediate removal of the same, and prosecute such removal diligently, and failure to do so shall be considered as an abandonment of such craft, and subject the same to removal by the United States as hereinafter provided for.

Penalties for violations of sections 13, 14, 15.

SEC. 16. That every person and every corporation that shall violate, or that shall knowingly aid, abet, authorize, or instigate a violation of the provisions of sections thirteen, fourteen and fifteen of this Act shall be guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding twenty-five hundred dollars nor less than five hundred dollars, or by imprisonment (in the case of a natural person) for not less than thirty days nor more than one year, or by both such fine and imprisonment, in the discretion of the court, one-half of said fine to be paid to the person or persons giving information which shall lead to conviction. And any and every master, pilot, and engineer, or person or persons acting in such capacity, respectively, on board of any boat or vessel who shall knowingly engage in towing any scow, boat, or vessel loaded with any material specified in section thirteen of this Act to any point or place of deposit or discharge in any harbor or navigable water, elsewhere than within the limits defined and permitted by the Secretary of War, or who shall wilfully injure or destroy any work of the United States contemplated in section fourteen of this Act, or who shall wilfully obstruct the channel of any waterway in the manner contemplated in section fifteen of this Act, shall be deemed guilty of a violation of this Act, and shall upon conviction be punished as hereinbefore provided in this section, and shall also have his license revoked or suspended for a term to be fixed by the judge before whom tried and convicted. And any boat, vessel, scow, raft, or other craft used or employed in violating any of the provisions of sections thirteen, fourteen and fifteen of this Act shall be liable for the pecuniary penalties specified in this section, and in addition thereto for the amount of the damages done by said boat, vessel, scow, raft, or other craft, which latter sum shall be placed to the credit of the appropriation for the im-

provement of the harbor or waterway in which the damage occurred, and said boat, vessel, scow, raft, or other craft may be proceeded against summarily by way of libel in any district court of the United States having jurisdiction thereof.

Department of Justice to enforce the law.

SEC. 17. That the Department of Justice shall conduct the legal proceedings necessary to enforce the foregoing provisions of sections nine to sixteen, inclusive, of this Act, and it shall be the duty of district attorneys of the United States to vigorously prosecute all offenders against the same whenever requested to do so by the Secretary of War or by any of the officials hereinafter designated, and it shall furthermore be the duty of said district attorneys to report to the Attorney-General of the United States the action taken by him against offenders so reported, and a transcript of such reports shall be transmitted to the Secretary of War by the Attorney-General; and for the better enforcement of the said provisions and to facilitate the detection and bringing to punishment of such offenders, the officers and agents of the United States in charge of river and harbor improvements, and the assistant engineers and inspectors employed under them by authority of the Secretary of War, and the United States collectors of customs and other revenue officers shall have power and authority to swear out process and to arrest and take into custody, with or without process, any person or persons who may commit any of the acts or offenses prohibited by the aforesaid sections of this Act, or who may violate any of the provisions of the same: *Provided*, That no person shall be arrested without process for any offense not committed in the presence of some one of the aforesaid officials: *And provided further*, That whenever an arrest is made under the provisions of this Act, the person so arrested shall be brought forthwith before a commissioner, judge, or court of the United States for examination of the offenses alleged against him; and such commissioner, judge, or court shall proceed in respect thereto as authorized by law in case of crimes against the United States.

Bridges obstructing navigation.

SEC. 18. That whenever the Secretary of War shall have good reason to believe that any railroad or other bridge now constructed, or which may hereafter be constructed, over any of the navigable waterways of the United States is an unreasonable obstruction to the free navigation of such waters on account of insufficient height, width of span, or otherwise, or where there is difficulty in passing the draw opening or the draw span of such bridge by rafts, steamboats, or other water craft, it shall be the duty of the said Secretary, first giving the parties reasonable opportunity to be heard, to give notice to the persons or corporations owning or controlling such bridge so to alter the same as to render navigation through or under it reasonably free, easy, and unobstructed: and in giving such notice he shall specify the changes recommended by the Chief of Engineers that are required to be made, and shall prescribe in each case a reasonable time in which to make them. If at the end of such time the alteration has not been made, the Secretary of War shall forthwith notify the United States district attorney for the district in which such bridge is situated, to the end that the criminal proceedings hereinafter mentioned may be taken. If the persons, corporation, or association owning or controlling any railroad or other bridge shall, after receiving notice to that effect, as hereinbefore required, from the Secretary of War, and within the time prescribed by him wilfully fail or refuse to remove the same or to comply with the lawful order of the Secretary of War in the premises, such persons, corporation, or association shall be deemed guilty of a misdemeanor, and on conviction thereof

shall be punished by a fine not exceeding five thousand dollars, and every month such persons, corporation, or association shall remain in default in respect to the removal or alteration of such bridge shall be deemed a new offense, and subject the persons, corporation, or association so offending to the penalties above prescribed: *Provided,* That in any case arising under the provisions of this section an appeal or writ of error may be taken from the district courts or from the existing circuit courts direct to the Supreme Court either by the United States or by the defendants.

Removal of wrecks.

SEC. 19. That whenever the navigation of any river, lake, harbor, sound, bay, canal, or other navigable waters of the United States shall be obstructed or endangered by any sunken vessel, boat, water craft, raft, or other similar obstruction, and such obstruction has existed for a longer period than thirty days, or whenever the abandonment of such obstruction can be legally established in a less space of time, the sunken vessel, boat, water craft, raft, or other obstruction shall be subject to be broken up, removed, sold, or otherwise disposed of by the Secretary of War at his discretion, without liability for any damage to the owners of the same: *Provided,* That in his discretion, the Secretary of War may cause reasonable notice of such obstruction of not less than thirty days, unless the legal abandonment of the obstruction can be established in a less time, to be given by publication, addressed "To whom it may concern," in a newspaper published nearest to the locality of the obstruction, requiring the removal thereof: *And provided also,* That the Secretary of War may, in his discretion, at or after the time of giving such notice, cause sealed proposals to be solicited by public advertisement, giving reasonable notice of not less than ten days, for the removal of such obstruction as soon as possible after the expiration of the above specified thirty days' notice, in case it has not in the meantime been so removed, these proposals and contracts, at his discretion, to be conditioned that such vessel, boat, water craft, raft, or other obstruction, and all cargo and property contained therein, shall become the property of the contractor, and the contract shall be awarded to the bidder making the proposition most advantageous to the United States: *Provided,* That such bidder shall give satisfactory security to execute the work: *Provided further,* That any money received from the sale of any such wreck, or from any contractor for the removal of wrecks, under this paragraph shall be covered into the Treasury of the United States.

In emergent cases Secretary of War may take immediate possession of and remove wrecks.

SEC. 20. That under emergency, in the case of any vessel, boat, water craft, or raft, or other similar obstruction, sinking or grounding, or being unnecessarily delayed in any government canal or lock, or in any navigable waters mentioned in section nineteen, in such manner as to stop, seriously interfere with, or specially endanger navigation, in the opinion of the Secretary of War, or any agent of the United States to whom the Secretary may delegate proper authority, the Secretary of War or any such agent shall have the right to take immediate possession of such boat, vessel, or other water craft, or raft, so far as to remove or to destroy it and to clear immediately the canal, lock, or navigable waters aforesaid of the obstruction thereby caused, using his best judgment to prevent any unnecessary injury; and no one shall interfere with or prevent such removal or destruction: *Provided,* That the officer or agent charged with the removal or destruction of an obstruction under this section may in his discretion give notice in writing to the owners of any such obstruction requiring them to remove it; *And provided further,*

That the expense of removing any such obstruction as aforesaid shall be a charge against such craft and cargo; and if the owners thereof fail or refuse to reimburse the United States for such expense within thirty days after notification, then the officer or agent aforesaid may sell the craft or cargo, or any part thereof that may not have been destroyed in removal, and the proceeds of such sale shall be covered into the Treasury of the United States.

Appropriation for removing wrecks.

Such sum of money as may be necessary to execute this section and the preceding section of this Act is hereby appropriated out of any money in the Treasury not otherwise appropriated, to be paid out on the requisition of the Secretary of War.

Repeal of previous laws. (As amended by section 12 of the river and harbor Act approved June 13, 1902, vol. 32, p. 375.)

That all laws or parts of laws inconsistent with the foregoing sections nine to twenty, inclusive, of this Act are hereby repealed: *Provided*, that no action begun or right of action accrued prior to the passage of this Act shall be affected by this repeal: *Provided further*, That nothing contained in the said foregoing sections shall be construed as repealing, modifying, or in any manner affecting the provisions of an Act of Congress approved June twenty-ninth, eighteen hundred and eighty-eight, entitled "An Act to prevent obstructive and injurious deposits within the harbor and adjacent waters of New York City, by dumping, or otherwise, and to punish or prevent such offenses, as amended by section three of the river and harbor Act of August eighteenth, eighteen hundred and ninety-four.

EXTRACT FROM THE RIVER AND HARBOR ACT APPROVED JUNE 13, 1902.

Enforcing rules for navigable waters.

SEC. 6. That any regulations heretofore or hereafter prescribed by the Secretary of War in pursuance of the fourth and fifth sections of the river and harbor Act of August eighteenth, eighteen hundred and ninety-four, and any regulations hereafter prescribed in pursuance of the aforesaid section four as amended by section eleven of this Act, may be enforced as provided in section seventeen of the river and harbor Act of March third, eighteen hundred and ninety-nine, the provisions whereof are hereby made applicable to the said regulations.

Bridges and rights of way across Illinois and Mississippi Canal.

SEC. 10. That the provisions of section nine of the river and harbor Act of March third, eighteen hundred and ninety-nine, are hereby made applicable alike to the completed and uncompleted portions of the Illinois and Mississippi Canal. Whenever the Secretary of War shall approve plans for a bridge to be built across said canal he may, in his discretion, and subject to such terms and conditions as in his judgment are equitable, expedient, and just to the public, grant to the person or corporation building and owning such bridge a right of way across the lands of the United States on either side of and adjacent to the said canal; also the privilege of occupying so much of said lands as may be necessary for the piers, abutments, and other portions of the bridge structure and approaches.

EXTRACT FROM THE RIVER AND HARBOR ACT OF AUGUST 18, 1894.

Regulations, canals and similar works.

SEC. 4. [As amended by section 11 of the river and harbor Act of June 13, 1902.] That it shall be the duty of the Secretary of War to prescribe such rules and regulations for the use, administration, and

navigation of any or all canals and similar works of navigation that now are, or that hereafter may be, owned, operated, or maintained by the United States as in his judgment the public necessity may require; and he is also authorized to prescribe regulations to govern the speed and movement of vessels and other water craft in any public navigable channel which has been improved under authority of Congress, whenever, in his judgment, such regulations are necessary to protect such improved channels from injury, or to prevent interference with the operations of the United States in improving navigable waters or injury to any plant that may be employed in such operations. Such rules and regulations shall be posted, in conspicuous and appropriate places, for the information of the public; and every person and every corporation which shall violate such rules and regulations shall be deemed guilty of a misdemeanor, and on conviction thereof in any district court of the United States within whose territorial jurisdiction such offense may have been committed, shall be punished by a fine not exceeding five hundred dollars, or by imprisonment (in the case of a natural person) not exceeding six months, in the discretion of the court.

Drawbridges. Regulations for opening to be published.

SEC. 5. That it shall be the duty of all persons owning, operating, and tending the drawbridges now built, or which may hereafter be built across the navigable rivers and other waters of the United States, to open, or cause to be opened, the draws of such bridges under such rules and regulations as in the opinion of the Secretary of War the public interests require to govern the opening of drawbridges for the passage of vessels and other water crafts, and such rules and regulations, when so made and published, shall have the force of law. Every such person who shall wilfully fail or refuse to open, or cause to be opened, the draw of any such bridge for the passage of a boat or boats, or who shall unreasonably delay the opening of said draw after reasonable signal shall have been given, as provided in such regulations, shall be deemed guilty of a misdeameanor, and on conviction thereof shall be punished by a fine of not more than two thousand dollars nor less than one thousand dollars, or by imprisonment (in the case of a natural person) for not exceeding one year, or by both such fine and imprisonment, in the discretion of the court: *Provided,* That the proper action to enforce the provisions of this section may be commenced before any commissioner, judge, or court of the United States, and such commissioner, judge, or court shall proceed in respect thereto as authorized by law in case of crimes against the United States: *Provided further,* That whenever, in the opinion of the Secretary of War, the public interests require it, he may make rules and regulations to govern the opening of drawbridges for the passage of vessels and other water crafts, and such rules and regulations, when so made and published, shall have the force of law, and any violation thereof shall be punished as hereinbefore provided.

ACT APPROVED MAY 9, 1900.

Chapter 387.—An Act authorizing the Secretary of War to make regulations governing the running of loose logs, steamboats, and rafts on certain rivers and streams.

Navigation. Exemption from prohibition against floating sack rafts in streams navigated by steamboats.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the prohibition contained in section fifteen of the river and harbor Act, approved March third, eighteen hundred and ninety-nine, against floating loose timber and logs, or sack rafts, so-called, of timber and logs in streams or channels

actually navigated by steamboats, shall not apply to any navigable river or waterway of the United States or any part thereof whereon the floating of loose timber and logs and sack rafts of timber and logs is the principal method of navigation. But such method of navigation on such river or waterway or part thereof shall be subject to the rules and regulations prescribed by the Secretary of War as hereinafter provided.

Secretary of War to make regulations for floating logs, rafts, etc.

SEC. 2. That the Secretary of War shall have power, and he is hereby authorized and directed, within the shortest practicable time after the passage hereof, to prescribe rules and regulations, which he may at any time modify, to govern and regulate the floating of loose timber and logs, and sack rafts (so-called) of timber and logs and other methods of navigation on the streams and waterways, or any thereof, of the character, as to navigation, in section one hereof described. The said rules and regulations shall be so framed as to equitably adjust conflicting interests between the different methods or forms of navigation; and the said rules and regulations shall be published at least once in such newspaper or newspapers of general circulation as in the opinion of the Secretary of War shall be best adapted to give notice of said rules and regulations to persons affected thereby and locally interested therein. And all modifications of said rules and regulations shall be similarly published. And such rules and regulations when so prescribed and published as to any such stream or waterway shall have the force of law, and any violation thereof shall be a misdemeanor, and every person convicted of such violation shall be punished by a fine of not exceeding two thousand five hundred dollars nor less than five hundred dollars, or by imprisonment (in case of a natural person) for not less than thirty days nor more than one year, or by both such fine and imprisonment, in the discretion of the court: *Provided*, That the proper action to enforce the provisions of this section may be commenced before any commissioner, judge, or court of the United States, and such commissioner, judge, or court shall proceed in respect thereto as authorized by law in the case of crimes or misdemeanors committed against the United States.

Amendment.

SEC. 3. That the right to alter, amend, or repeal this Act at any time is hereby reserved.

Pending actions unaffected.

SEC. 4. That this Act shall not, nor shall any rules or regulations prescribed thereunder, in any manner affect any civil action or actions heretofore commenced and now pending to recover damages claimed to have been sustained by reason of the violation of any of the terms of said section fifteen, as originally enacted, or in violation of any other law.

Approved, May 9, 1900.

EXTRACT FROM THE RIVER AND HARBOR ACT APPROVED MARCH 3, 1905.

Secretary of War to make regulations for transportation and dumping of dredgings, etc.

SEC. 4. That the Secretary of War is hereby authorized and empowered to prescribe regulations to govern the transportation and dumping into any navigable water, or waters adjacent thereto, of dredgings, earth, garbage, and other refuse materials of every kind or description, whenever in his judgment such regulations are required in the interest of navigation. Such regulations shall be posted in conspicuous and appropriate places for the information of the public; and every person or corporation which shall violate the said regulations, or any of them

shall be deemed guilty of a misdemeanor and shall be subject to the penalties prescribed in section sixteen of the river and harbor Act of March third, eighteen hundred and ninety-nine, for violation of the provisions of section thirteen of the said Act: *Provided,* That any regulations made in pursuance hereof may be enforced as provided in section seventeen of the aforesaid Act of March third, eighteen hundred and ninety-nine, the provisions whereof are hereby made applicable to the said regulations: *Provided further,* That this section shall not apply to any waters within the jurisdictional boundaries of any State which are now or may hereafter be used for the cultivation of oysters under the laws of such State, except navigable channels which have been or may hereafter be improved by the United States, or to be designated as navigable channels by competent authority, and in making such improvements of channels, the material dredged shall not be deposited upon any ground in use in accordance with the laws of such State for the cultivation of oysters, except in compliance with said laws: *And provided further,* That any expense necessary in executing this section may be paid from funds available for the improvement of the harbor or waterway, for which regulations may be prescribed, and in case no such funds are available the said expense may be paid from appropriations made by Congress for examinations, surveys and contingencies of rivers and harbors.

Expenses incidental to examinations, etc., relative to bridges, harbor lines, etc.

SEC. 6. That expenses incurred by the Engineer Department in all investigations, inspections, hearings, reports, service of notice, or other action incidental to examination of plans or sites of bridges or other structures built or proposed to be built in or over navigable waters, or to examinations into alleged violations of laws for the protection and preservation of navigable waters, or to the establishment or marking of harbor lines, shall be payable from any funds which may be available for the improvement, maintenance, operation, or care of the waterways or harbors affected, or if such funds are not available in sums judged by the Chief of Engineers to be adequate, then from any funds available for examinations, surveys and contingencies of rivers and harbors.

ENGLISH TRACK ON THE PENNSYLVANIA RAILROAD.

By Jos. T. Richards,
Chief Engineer of Maintenance of Way.

In the middle eighties, Mr. Frank Thomson, then Second Vice-President of the Pennsylvania Railroad Company, while abroad became interested in the question of the comparative merits of English and American track.

He accordingly authorized the purchase of two miles of London & North Western Railroad standard track for trial in comparison with American standard track under American conditions.

In order to give the track a fair trial it was distributed among the four main line divisions (one-half mile to each), so that it would have different roadbed, different climate and different men to care for it, watch and record its performance and make the final decision, which was thought to be the most impartial way of making the test of this track as compared with ours. The New York Division has a sandy, well-drained roadbed, the Philadelphia Division runs through a loamy, rich farming section, while the Middle and Pittsburgh divisions are in mountainous and rocky country.

There was also a discussion at that time as to the comparative merits of track laid with metal and wooden cross-ties. For this reason, in one-half of the two miles, metal ties were used and wooden ties in the other half. Also, metal keys were used with the metal ties and white oak keys on the sections laid with wooden ties.

The trial was made on first-class roadbed with stone ballast, with the result, as shown in the report, that the English track did not last as long as the American type (the former having an average life of five years and the latter ten or more years), that the metal ties were not as satisfactory for holding the track in line and the metal wedges failed and had to be replaced with wooden ones and the metal ties did not last as long as the wooden; also that the metal in the English rail did not last as long as the metal in the American rail.

The cost was about twice as much (both first cost and cost of maintenance) as that of Pennsylvania Railroad standard track.

REPORT ON THE ENGLISH TRACK LAID ON THE PENNSYLVANIA RAILROAD, 1887, 1888.*

The two miles of "English track" laid in the four main line divisions of the Pennsylvania Railroad between Jersey City and Pittsburgh was of the London & North Western Railway standard, and was of two types, viz.:

(1) 1 mile laid with *metal* sleepers (cross-ties).
(2) 1 mile laid with *wooden* sleepers (cross-ties).

*Inspection and compilation of results in charge of Maintenance of Way Department, Jos. T. Richards, Chief Engineer of Maintenance of Way.

The steel rails of this standard are known as the "Bull-head pattern," 90 lbs. per yard (see page 293), differing from the P. R. R. T-rail (see page 293) in that it is "double headed" instead of having a flat base. They were made by the Darlington Steel & Iron Company, Darlington, England, to the following specifications:

"LONDON & NORTH WESTERN RAILWAY.

"Specifications for Bessemer Steel Rails.

"The London & North Western Railway Company require —— tons of rails.

"The rails are to be 'bull-headed,' according to the template provided by the Company, of which the sketch at the foot of this page is a copy, weighing not less than 89 and not more than 91 lbs. per yard; they are to be rolled in lenghts of 30 ft. each; to be perfectly straight and true, and of uniform section throughout their entire length.

"The ends are to be cut square off.

"The finishing groove of the rolls is to bear the maker's name, the date of rolling and the following letters, 'L. N. W. R. Steel.'

"The rails are to be fish-jointed, and must have at each end two holes, each 1⅛ of an inch in diameter, drilled through the web out of the solid, so as not to raise any projection beyond the uniform surface of the rail, and so as to insure the fish plate accurately fitting the rail for its entire length.

"The holes are to be drilled in accordance with the template which will be supplied to the contractor.

"The Company shall be at liberty (if they deem it necessary) to send their Engineer, or his assistant, to the Works to examine or superintend the mode of manufacture, and to reject such rails as he may consider unfit for use.

"Each rail is to be made from an ingot not less than 10 in. square at the smaller end and of sufficient weight to allow all the unsound part to be cut off each end of the rail, leaving the finished rail sound throughout its entire length.

"The ingot may be reduced either by hammering or rolling, at the option of the maker, but he must state when tendering which method he proposes to adopt.

"The rail must stand without breaking a permanent deflection of three (3) inches in a length of 3 ft. This deflection must be produced by one blow of a weight falling from a height of not less than 20 ft. upon the center of a rail placed head uppermost upon two supports 3 ft. apart.

"The pieces of rail tested need not exceed 3 ft. 6 in. in length, but they must be cut from rails which are average samples of the make, selected haphazard by the Company's Engineer.

"A number of rails not exceeding in weight 10 per cent. of the total weight delivered will be accepted by the Company if cut to any of the

following lengths, viz.: 27, 24, 21, 18 or 15 ft., provided that they have not been cut from rails which have failed under the falling weight test or are of inferior quality in any respect or have been purposely rolled of a length shorter than 30 ft.

"The Contractor will not be permitted to sub-let the manufacture of these rails.

"The Contractor must deliver the whole of the rails by the end of ——— in such weekly installments as may be agreed upon.

"Correct invoices of every delivery, stating the number of rails in each wagon, must be sent addressed as shall be directed, and no rails will be considered received until certified in writing by the party to whom they are to be sent.

"Payments in cash will be made within two months of the date of each delivery, provided the rails are found in all respects satisfactory.

"The accompanying form of tender to be filled up and forwarded to the Stores Committee not later than 10 o'clock on ———, marked outside, 'Tender for Rails.'

"Euston Station, London, ———, 187—."

"FORM OF TENDER.

"For Supplying the London & North Western Railway Company with Steel Rails.

"——— hereby agree to supply and deliver ——— tons of *Steel Rails, according to the terms and conditions set forth in the accompanying Specifications, at the following prices, viz.:

If delivered in Railway Wagons at ——— Station at ——— per ton.
If delivered in Railway Wagons at ——— Station at ——— per ton.
If delivered in Railway Wagons at ——— Station at ——— per ton.

"——— further agree to allow a reduction of One Pound (£1) for each ton of Rails which may not be delivered by the time stated in the Specifications; such deduction to be made from any money which may be due by the Company to ——— on account of previous deliveries, and also to guarantee them against failure from imperfections of manufacture or faulty material, for a period of ——— years.

"Name .....

"Address .....

"Date .....

"To The Stores Committee, London & North Western Railway Company, Euston Station, London.

"*(Here insert hammered or rolled.)"

These English rails are carried in chairs and held in place by a wooden key, 6 in. long, driven between the rail and the chair. The connection between the metal cross-tie and the chair is riveted. In the wooden tie it is made by lag screws and drive-bolts—all as shown on plans herewith.

The cross-ties of both kinds are 9 ft. long, those of wood being 10 in. wide by 5 in. thick. In this instance the Pennsylvania Railroad standard white oak cross-tie, 8½ ft. long, of selected width, were used. In both types 10 ties are laid to every 30 ft.

The comparative weight of track material laid with both kinds of cross-ties is as follows:

METAL CROSS-TIES.

	lbs.	lbs.
One steel cross-tie	136	
Two steel chairs for connections	48	
		184

WOODEN CROSS-TIES.

One wooden cross-tie	140	
Two cast iron chairs	90	
Bolts and screws	12	
		242
Difference in weight		58

The full bill of material, exclusive of the wooden ties, for the two miles of track received from England, and the cost of same delivered in New York City, was as follows:

BILL OF MATERIALS FOR TWO MILES ENGLISH TRACK.

(One mile wooden ties; one mile steel sleepers.)

704	Steel rails	$ 5,565.99
1,428	Steel fish plates	416.52
1,760	Steel sleepers	4,273.65
3,520	Cast-iron chairs	919.89
3,570	Steel keys	221.80
2,896	Fish bolts and hexagon nuts	99.78
7,040	Spikes	126.95
7,040	Galvanized screws	288.74
7,040	Oak ferrules	42.77
3,570	Oak keys	63.32
	Marine insurance	54.68
	Packing	17.74
	Consul's certificate and bill of lading	3.40
	Commission for advancing money	302.37
	Duty paid	11,459.94
	Freight (Middleboro to New York)	1,838.68
	Custom house brokerage and fees	3.60
		$25,699.82
	Additional expenses:	
	3,520 pieces tarred felt, 387 iron chairs, duties, etc.	412.88
		$26,112.70

The above bill provided for the laying of one mile of single track with steel cross-ties and one mile with wooden cross-ties, and was laid in half-mile sections as follows:

New York Division—½ mile laid with steel ties.
Philadelphia Division—½ mile laid with wooden ties.
Middle Division—½ mile laid with steel ties.
Pittsburgh Division—½ mile laid with wooden ties.

To lay a half mile of track of each type, the following material was required:

For One-half Mile of Track with Steel Ties

176 Steel rails, each 30 ft. long.
352 Fish plates.
880 Steel sleepers complete (10 to a 30-ft. rail), 9 ft. long.
704 Bolts with hexagon nuts.
1,760 Steel keys.

For One-half Mile of Track with Wooden Ties

176 Steel rails, each 30 ft. long.
352 Fish plates.
880 Wooden sleepers (cross-ties), 10 to 30-ft. rail, P. R. R. standard, 8½ ft. long, selected width.
1,760 Cast-iron chairs (45 lbs. each).
704 Bolts and hexagon nuts.
3,520 Galvanized screws.
3,520 Spikes.
3,520 Creosoted oak ferrules.
1,760 Pieces of felt punched for chairs.
1,760 Creosoted compressed oak keys.

The cost of material and expense of laying one-half mile of each type was as follows:

NEW YORK DIVISION—WITH STEEL RAILS.

176	Steel rails	$1,391.54
358	Fish plates	104.50
880	Sleepers	2,136.83
718	Fish bolts and hexagon nuts	24.85
1,785	Steel keys	110.90
	Marine insurance	17.06
	Cost of packing	5.53
	Consul's certificate and bill of lading	1.06
	Commission	94.89
	Duty	3,667.76
	Freight	584.75
	Custom house brokerage and fees	3.50
	Drayage	0.32
		$8,143.49

	Labor Laying:		
	Laying track and ballasting	$301.58	
	Unloading ballast	123.69	
			425.27
			$8,568.76

PHILADELPHIA DIVISION—WITH WOODEN TIES

176	Steel rails		$1,391.54
358	Fish plates		104.50
880	Wooden sleepers, P. R. R. standard, at 75c (estimated)		660.00
1,760	Cast-iron chairs		459.94
718	Fish bolts and hexagon nuts		24.85
3,520	Galvanized screws		144.37
3,520	Spikes		63.47
3,520	Oak ferrules		21.38
1,785	Oak keys		63.32
	Marine insurance		10.28
	Cost of packing		3.34
	Consul's certificate and bill of lading		0.64
	Commission		56.29
	Duty		2,062.21
	Freight		334.59
1,760	Pieces felt, 193 iron chairs, duties, etc.		206.44
			$5,607.16
	Labor:		
	Ballasting	$ 36.00	
	Framing ties for chairs	91.20	
	Removing track	134.80	
	Laying ties	126.00	
	Laying rails	74.40	
	Surfacing	77.40	
			539.80
			$6,146.96

MIDDLE DIVISION—WITH STEEL TIES.

176	Steel rails		$1,391.54
358	Fish plates		104.50
880	Steel sleepers		2,136.83
718	Fish bolts and hexagonal nuts		24.85
1,785	Steel keys		110.90
	Marine insurance		17.06
	Cost of packing		5.53
	Consul's certificate and bill of lading		1.06
	Commission		94.89
	Duty		3,667.76
	Freight		584.75
275.22	Cubic yards ballast		207.41
			$8,347.08

	Labor:		
	Removing old track	$351.50	
	Laying ties	175.50	
	Laying rails	104.00	
	Ballasting	425.80	
	Surfacing, etc.	324.44	
			1,381.24
			$9,728.32

PITTSBURGH DIVISION—WITH WOODEN TIES.

176	Steel Rails	$1,391.54
833	Cross-ties	524.79
358	Fish plates	104.50
718	Fish bolts and hexagonal nuts	24.85
1,760	Cast-iron chairs	459.94
3,520	Spikes	63.47
3,520	Galvanized screws	144.37
3,520	Oak ferrules	21.38
1,785	Keys (oak)	63.32
	Marine insurance	10.28
	Cost of packing	3.34
	Consul's certificate and bill of lading	0.64
	Commission	56.29
	Duty	2,062.21
	Freight	334.59
1,760	Pieces tarred felt, 193 iron chairs, duties	206.44
1,250	Cubic yards ballast	1,250.00
		$6,721.95

	Labor:		
	*Removing old track		
	Framing ties for chairs	$298.10	
	Laying rails	291.68	
	Laying ties	33.87	
	Ballasting	412.33	
	Surfacing, etc.	295.28	
			1,331.26
			$8,053.21

RECAPITULATION.

Steel Sleepers.

	New York Division:		
	Material	$8,143.49	
	Labor	425.27	
			$ 8,568.76
	Middle Division:		
	Material	$8,347.08	
	Labor	1,381.24	
			9,728.32

*New third track.

Wooden Ties.	Philadelphia Division:		
	Material	$5,607.16	
	Labor	539.80	
			6,146.96
	Pittsburgh Division:		
	Material	$6,721.95	
	Labor	1,331.26	
			8,053.21
	Total—2 miles English track		$32,497.25

SUMMARY.

	Wooden Ties, 1 mile.	Steel Sleepers, 1 mile.	Totals, 2 miles.
Labor	$ 1,871.06	$ 1,806.51	$ 3,677.57
Material	12,329.11	16,490.57	28,819.68
Total	$14,200.17	$18,297.08	$32,497.25

The experience of the divisions whereon this track was laid is as follows, and is the result of careful observation during the time the track was in service:

NEW YORK DIVISION.

Laid in July, 1887, with steel cross-ties, between Robinvale and Menlo Park stations in eastbound (No. 1) passenger track between M. P. 24 + 3,407 and 24 + 977. Traffic in one direction only:

720 ft. on tangent.
1,710 ft. on 1 deg. 15 min. curve.

2,430 ft.—total ft. of track.

It was laid on descending grade .495 ft. per 100 ft. (26 ft. per mile).

This track was in continuous service up to October, 1895, when 1,005 ft. of it was removed. In June, 1896, the balance of 1,425 ft. of track was taken up, and 445 ft. was laid on the engine tracks at Mile Run Yard (New Brunswick) and 1,050 ft. laid in yard at Trenton.

The difficulty experienced with this track was the impossibility of keeping it from creeping and in proper line and surface, due to the fact that the metal cross-ties being lighter than wooden ones and having nothing to prevent their sliding on the ballast it was necessary to go over the track thoroughly at least six times a year and in two weeks it would again show bad line.

In 1893 the line had become so bad that it was necessary to place planking under the head of the rail and secured to the ties of the ad-

jacent No. 2 track (a P. R. R. standard) to prevent the track from shifting out of line.

The gage was never good, as the keys in the wrought-iron chairs which hold the rails to the ties spring with the weight of the trains and widen the gage.

The annual cost of maintaining this one-half mile of English track was as follows:

Year.	Amount.
1888	$ 124.56
1889	365.24
1890	452.12
1891	375.84
1892	424.67
1893	533.84
1894	373.71
1895	356.07

Total (8 years).....$3,006.05, or $375.50 per year, being at the rate of $751.00 per mile of track per year. The average cost per year of Pennsylvania Railroad standard track of 85-lb. rails at the same locality and having the same train service and within the same period was $621.85 per mile.

PHILADELPHIA DIVISION.

Laid in September, 1887, with wooden cross-ties east of Leaman Place on main eastbound passenger track, between M. P. 55 + 2,431 and M. P. 55 + 4,891 coming east.

385 ft. on 3-deg. curve.
680 ft. on tangent.
1,000 ft. on 4-deg curve.
395 ft. on tangent.

2,460 ft.—total.

The grade was about uniform throughout, 26 ft. per mile descending in the direction of the traffic.

The difficulty experienced on this division with this rail was in keeping the track in line and surface, and because of the creeping of the rails. P. R. R. standard track, built at the same time, showed no signs of creeping. The rail wore badly on the gage side of the rail, making the gage wide. The joints gave ordinary service only. The cast-iron chairs held in place well as long as the felt placed between it and the wooden tie lasted, when by cutting into the tie it became loose and some were broken in track. The increased bearing surface given by these chairs, which were 9 in. x 13 in., seemed to prolong the life of the tie somewhat. The wedges gave a lot of trouble in hot weather on account of getting loose and falling out.

This track was in continuous service 4 years 8 months, but could not be brought above a freight track standard in condition for over a year before it was removed. It was removed in June, 1892, at a cost of $300 and part has been relaid at the following points:

West Philadelphia, Shop Yard Siding..... 968 ft. track laid in 1892
West Philadelphia, Hickey's Yard Siding..... 398 ft. track laid in 1893
West Philadelphia, Park Shop No. 11 Siding.. 810 ft. track laid in 1893

2,176 ft.—total

The cost of maintenance of this track for the period of 4 years 8 months was $1,318.34, or at the rate of about $555 per mile per year. The cost of maintaining a similar stretch of P. R. R. standard 85-lb. rails in the same track (eastbound), both being exclusively passenger tracks at the same point for the same time, was $1,292.50, or about $544 per mile per year.

MIDDLE DIVISION.

Laid in September, 1887, with steel cross-ties, east of Huntingdon on main eastbound passenger track, between M. P. 200 + 4,800 and M. P. 201 + 2,040 = 2,520 ft., viz.:

275 ft. on 4-deg. curve.
575 ft. on 6-deg. curve.
1,670 ft. on tangent.

2,520 ft.—total.

Beginning at the west end and running eastward, it was laid on grades as follows:

+12.35 ft. per mile for a distance of 330 ft.
—11.00 ft. per mile for a distance of 300 ft.
+13.40 ft. per mile for a distance of 800 ft.
Level for a distance of 300 ft.
—16.04 ft. per mile for a distance of 790 ft.

This rail on straight track gave good service wearing smooth and evenly. On the inside of the high rail of curves the wear rendered the gage wide, which was overcome for awhile in April, 1891, by turning the rails.

The steel ties, however, were not a success, as they would not hold the track in good line; the tie being the shape of an inverted trough and only about half the weight of a wooden cross-tie, with the ballast tamped under it, forming a rigid support, it was free to move laterally, and the entire track lifted and was never as solid and substantial under heavy engines and cars as it should be—or as the American track.

The creeping of the rails was also a serious matter, as the splices coming in contact with the tie immediately in front of the joint would push it from its place, requiring considerable labor to shift the tie into position; the creeping in some places amounted to 10 and 12 in.

The wrought-iron chair did not prove to be a satisfactory holding device for the rail. The wedges placed between the inside of the chair and web of rail were difficult to keep in place, owing to the creeping of the rails. The rivets which held the chairs to the metal ties were generally loose when the track was taken up.

This track was removed in October, 1891, on account of the rails and metal ties being worn out, and none of it was relaid. It was in service 4 years and its total cost for maintenance during this time was $2,092.27, or about $1,021 per mile per year. The cost of maintaining the same length of P. R. R. standard track, 85 lbs., on westbound track opposite to the English track, for the same time (4 years), was $708.92, or about $355 per mile per year, a difference in favor of P. R. R. track of $666 per mile per year:

Comparative Statement of Cost of Maintenance of one-half mile of English and American Track

Year	Month	English Amount	American Amount	Year	Month	English Amount	American Amount
1887...	Sept.....	96.00	.....	1889...	Oct.....	.....	.....
1887...	Oct.....	199.44	.....	1889...	Nov.....	9.90	6.10
1887...	Nov.....	324.40	.....	1889...	Dec.....	13.75	27.50
1887...	Dec.....	57.60	.....	1890...	Jan.....	.....	.....
1888...	Jan.....	.....	.....	1890...	Feb.....	13.30	13.30
1888...	Feb.....	.....	.....	1890...	Mar.....	.....	.....
1888...	Mar.....	.....	.....	1890...	Apr.....	54.80	.....
1888...	Apr.....	66.40	58.40	1890...	May.....	38.40	19.20
1888...	May.....	31.20	10.40	1890...	June.....	14.40	19.20
1888...	June.....	19.60	.....	1890...	July.....	.....	.....
1888...	July.....	31.20	10.40	1890...	Aug.....	.....	50.10
1888...	Aug.....	122.59	97.35	1890...	Sept.....	63.00	.....
1888...	Sept.....	82.40	54.13	1890...	Oct.....	45.60	24.00
1888...	Oct.....	38.29	43.44	1890...	Nov.....	28.00	.....
1888...	Nov.....	25.50	.....	1890...	Dec.....	42.00	28.00
1888...	Dec.....	.....	26.40	1891...	Jan.....	.....	.....
1889...	Jan.....	42.00	24.20	1891...	Feb.....	56.00	11.60
1889...	Feb.....	.....	.....	1891...	Mar.....	46.00	.....
1889...	Mar.....	22.00	.....	1891...	Apr.....	84.00	35.00
1889...	Apr.....	26.70	.....	1891...	May.....	56.00	28.00
1889...	May.....	.....	21.60	1891...	June.....	84.00	14.00
1889...	June.....	.....	.....	1891...	July.....	96.80	33.80
1889...	July.....	11.00	.....	1891...	Aug.....	48.00	9.60
1889...	Aug.....	13.50	.....	1891...	Sept.....	78.00	Cost of removing
1889...	Sept.....	13.20	43.20				
Totals.....		1220.32	389.52			871.95	319.40

SUMMARY

Year	English Amount	American Amount
1887.....	677.44	.....
1888.....	414.48	300.52
1889.....	152.05	122.60
1890.....	299.50	153.80
1891.....	548.80	132.00
Totals.....	2092.27	708.92

A chemical analysis made at Altoona of a piece of this rail taken from the high side of curve showed the following:

	Most worn head.	Least worn head.
Carbon	0.28	0.28
Manganese	0.79	0.79
Phosphorus	0.059	0.060
Silicon	0.061	0.063
Sulphur	0.064	0.065
Copper	0.046	0.048

PITTSBURGH DIVISION.

Laid in October, 1887, with wooden cross-ties, west of Mineral Point in main eastbound passenger track on new roadbed, where third track system was extended eastward between M. P. 268 + 2,115 and M. P. 268 + 4,605:

619 ft. on 3-deg. curve.
671 ft. on tangent.
642 fft. on 3-deg. curve.
558 ft. on tangent.

2,490 ft.—total.

Beginning at the west end and running eastward, this track was laid to the following grade:

400 ft.—47.52 ft. per mile ascending.
2,000 ft.—42.24 ft. per mile ascending.
90 ft.—52.80 ft. per mile ascending.

2,490 ft.

The P. R. R. standard track, 2,500 ft. in length, it was compared with as to cost, etc., was the continuation of this same track west; 930 ft. east of this latter being new track and the balance, 1,570 ft., main track formerly in use. This track continued as our main eastbound track from this date, November 13, 1887, till April 13, 1891—three years and five months. Since the latter date named the south track has been operated as our eastbound freight track, the middle one being the main track. The traffic, however, is heavier on the freight track (on account of all eastbound freight trains using it) than on the main eastbound track.

Naturally the change in the manner of running the tracks at this point in April, 1891, from main to freight tracks has interfered with the English track being kept in as good condition as prior to the change, though it has been given a great deal of attention and has been kept in good condition.

The rails on straight line showed good wear, but on curves it was considerable and rapid and gave trouble by widening the gage.

As soon as the wear starts it increases rapidly, which is accelerated by the play given the wheels

The track in question was laid at the foot of a sliding hill, where the drainage was very bad, and for this reason we attribute the decay of the ties. We looked for the saving in using this pattern of track principally in the life of the ties and saving in cost of maintaining, but from the accompanying statement the figures are the other way 50 per cent. greater cost in maintaining, and the ties decaying, though showing greater life than the P. R. R. track, will not be sufficient to offset the increase in cost of maintaining.

The joints were not first-class—they being only plain, short fish bars of little vertical stiffness.

The cast-iron chairs answered well to protect the cross-ties and to support the "bull head" rail, but with an imperfect wedge for fastening the rail to the chair.

The track was removed in October, 1895, and has since been placed in Wall Yard Shop tracks.

The cost of maintenance of this track, as compared with a corresponding length of P. R. R. standard track of 85-lb. rails, is as follows:

Year.	English.	P. R. R.
1887	$ 70.77	$ 18.70
1888	458.94	178.56
1889	125.59	119.54
1890	158.31	85.07
1891	103.14	79.97
1892	179.12	69.63
1893	143.85	72.40
1894	243.00	153.00
1895	125.00	51.00
	$1,607.78	$ 827.87

The above cost of maintenance for 8 years was at the rate of about $402 per mile per year for the English track, and $207 per mile per year for P. R. R. standard.

The details of cost and annual maintenance of this track on the Pittsburgh Division is as follows:

Cost: (When laid.)		
5,000 ft. 90-lb. steel rails, 66.97 tons at $42.50		$2,846.22
1,685 English chairs	$ 952.02	
1,678 English bolts	73.83	
1,700 English oak keys	68.00	
3,370 English ferrules	50.55	
3,400 Screws	306.00	
685 Bolts and nuts	51.37	
342 Splice bars	215.46	
3,700 Spikes	136.90	
		1,854.13

Removing old rail		
Framing ties for chairs	$ 298.10	
Laying ties	33.87	
Laying rails	291.68	
Ballasting	412.33	
Surfacing	228.88	
Hauling rails and splice material	48.00	
Hauling ties	18.40	
		1,331.26
833 Cross-ties	$ 524.79	
1,250 Cubic yards ballast	1,250.00	
		1,774.79
Total cost		$7,806.40

Maintaining:

1887—December—English:		
Surfacing	$ 30.47	
Keeping in wooden keys	40.30	
		$ 70.77
American:		
Surfacing		18.70
1888—January—No charge.		
February—English:		
Surfacing	$ 2.17	
Watching	2.60	
		4.77
American:		
Surfacing		7.21
March—English:		
Surfacing		11.70
American:		
Surfacing	$ 5.79	
Tightening bolts	.65	
		6.44
April—English		
Surfacing	$115.30	
Lining	5.85	
Taking off chairs broken by wreck and replacing with new	11.70	
		132.85
American:		
Surfacing	$ 20.40	
Lining	4.80	
		25.20
May—English:		
Surfacing	$ 5.13	
		5.13

American:		
Surfacing	$ 2.60	
		2.60
June—No charge.		
July—English:		
Surfacing	$ 42.90	
		42.90
American:		
Surfacing	$ 33.80	
		33.80
August—English:		
Line	$ 3.12	
Surface	41.34	
New wedges	5.20	
Keeping joints in proper shape	1.39	
Keeping lag screws and rail fastenings in place	3.90	
Miscellaneous	3.90	
		58.85
American:		
Line	$ .62	
Surface	7.08	
New spikes	.26	
Keeping splices in shape	.13	
Spiking	.13	
Miscellaneous	1.30	
		9.52
September—English:		
Line	$ 2.86	
Surface	24.30	
New wedges	2.60	
Keeping joints in proper shape	3.64	
Keeping lag screws and rail fastenings in place	1.95	
		35.35
American:		
Line	$ 1.43	
Surface	41.60	
Keeping splices in shape	.65	
Spiking	.26	
		43.94
October—English:		
Line	$ 23.40	
Surface	3.63	
New wedges	4.80	
Keeping wedges in place	2.60	
Keeping joints in proper place	1.10	
Keeping lag screws and fastenings in place	.75	
		36.28

American:		
Line	$ 11.10	
Surface	3.90	
Keeping splices in shape	.40	
Spiking	.26	
		15.66
November—English:		
Line	$ 1.80	
Surface	46.80	
Keeping lag screws and rail fastenings in place	.90	
		49.21
American:		
Line	$ 1.43	
Surface	15.60	
Keeping splices in shape	.65	
		17.68
December—English		
Surfacing	$ 1.30	
		1.30
American:		
Surfacing	$ .65	.65
Total 1888:		
English		$458.94
American		178.56
1889—January—English:		
Surfacing	$ 15.60	
		$ 15.60
American:		
February—No charge.		
March—English:		
Surfacing	$ 15.39	
		15.39
American:		
Surfacing	$ 38.37	
		38.37
April, May, June, July—No charge.		
August—English:		
Surfacing	$ 60.60	
Line	3.64	
		64.24
American:		
Surfacing	$ 60.60	
Line	3.64	64.24
September—No charge.		
October—English:		
Surfacing	$ 11.10	
Lining	6.84	
		17.94

American:		
Surfacing	$ 4.55	
Lining	2.28	
		6.83
November—No charge.		
December—English:		
Surfacing	$ 10.10	
Line	2.32	
		12.42
American:		
Surfacing	$ 10.10	
		10.10
Total 1889:		
English		$125.59
American		119.54
1890—January—English:		
Surfacing	$ 7.20	
Tightening bolts	.39	
		$ 7.59
American:		
Tightening bolts	$ .52	
		.52
February—English:		
Surfacing	$ 7.50	
Tightening bolts	.65	
		8.15
American:		
Surfacing	$ 7.50	
Tightening bolts	.65	
		8.15
March—No charge.		
April—English:		
Surfacing	$ 15.00	
Tightening bolts	.65	
Keeping wedges in position	.65	
		16.30
American:		
Surfacing	$ 7.50	
Tightening bolts	.65	
		8.15
May—English:		
Surfacing	$ 35.20	
Line	3.12	
Keeping joints tight	1.95	
Keeping wedges in place	1.30	
		41.57

American:		
Surfacing	$ 15.00	
Keeping joints tight	.65	
		15.65
June—English:		
Surfacing	$ 4.25	
Keeping wedges tight	1.30	
		5.55
American:		
200 lbs. spikes	$ 5.00	
Spiking to gage	16.60	
		21.60
July—No charge.		
August—English:		
Surfacing	$ 11.10	
Lining	1.30	
Keeping wedges tight	19.50	
Placing new wedges in track	1.30	
		33.20
American:		
Surfacing	$ 11.10	
		11.10
September—English:		
Surfacing	$ 15.00	
Lining	1.50	
Attention to joints	.65	
		17.15
American:		
Surfacing	$ 12.40	
		12.40
October—No charge.		
November—English:		
Surfacing	$ 7.50	
Lining	1.30	
		8.80
American:		
Surfacing	$ 7.50	
		7.50
December—No charge.		
Total 1890:		
English		$158.31
American		85.07
1891—January and February—No charge.		
March—English:		
Surfacing	$ 16.30	
Attention to joints	.65	
		$ 16.95

American:		
Surfacing	$ 7.50	
Attention to joints	.65	
		8.15
April and May—No charge.		
June—English:		
Surfacing	$ 15.00	
		15.00
American:		
Surfacing	$ 12.40	
		12.40
July—English:		
Surfacing	$ 7.50	
Lining	1.30	
Keeping wedges tight	1.30	
		10.10
American:		
August—English:		
Keeping wedges tight	$ 0.65	
		.65
American:		
Surfacing	$ 12.00	
Lining	3.12	
		15.12
September—English:		
Surfacing	$ 28.00	
Lining	1.30	
Keeping wedges tight	.65	
		29.65
American:		
Surfacing	$ 6.20	
		6.20
October—English:		
Lining	$ 1.75	
Tightening wedges	1.30	
		3.05
American:		
Tightening bolts	$ .65	
		.65
November—English:		
Surfacing	$ 7.50	
Tightening bolts	.65	
Lining	.65	
Keeping wedges in shape	.39	
		9.19
American:		
Surfacing	$ 6.85	
Lining	.65	
		7.50

December—English:		
Surfacing	$ 15.00	
Lining	1.30	
Keeping blocks in shape	1.95	
		18.25
American:		
Surfacing	$ 7.15	
Spiking	21.50	
Lining	1.30	
		29.95
Total 1891:		
English		$103.14
American		79.97
1892—January—February—March—No charge.		
April—English:		
Surfacing	$ 15.00	
Keeping joints in shape	1.30	
		$ 16.30
American:		
Surfacing	$ 8.50	
Keeping joints in shape	1.30	
		9.80
May—English:		
Surfacing	$ 85.00	
Lining	7.50	
Keeping joints in shape	.65	
Keeping wedges tight	2.30	
		95.45
American:		
Surfacing	$ 15.00	
Lining	1.80	
Keeping joints tight	1.30	
		18.10
June—English:		
Keeping wedges tight	$ 3.90	
		3.90
American:		
July—English:		
Keeping wedges tight	$ 1.30	
Keeping joints in place	.65	
		1.95
American:		
August—English:		
Line	$ 4.16	
Surface	14.30	
Keeping wedges tight	2.60	
		21.06

American:
Line ..... $ 2.06
Surface 4.68
6.76

September—English:
Line ..... $ 2.40
Surface 9.30
11.70

American:
Line ..... $ 7.20
Surface 24.00
31.20

October—English:
Line ..... $ 3.90
Surface 12.09
Keeping joints in shape 2.17
18.16

American:
Line ..... $ .65
Surface 1.30
1.95

November—English:
Line ..... $ 3.90
Keeping joints in shape 1.30
5.20

American:

December—English:
Surfacing ..... $ 4.81
Keeping wedges tight ..... .65
5.46

American:
Surfacing ..... $ 1.82
1.82

Total 1892:
English $179.18
American 69.63

1893—January and February—No charge.

March—English:
Line ..... $ 1.30
Surface 2.60
$ 3.90

American:
Line ..... $ 2.60
Surface 5.90
8.50

April—English:
Keeping joints in shape ..... $ 1.95
1.95

American:		
Surfacing	$ 3.90	
		3.90
May—English:		
Surfacing	$ 9.00	
Keeping wedges tight	1.00	
		10.00
American:		
Surfacing	$ 9.00	
Keeping joints in shape	1.00	
		10.00
June—English:		
Keeping joints in shape	$ 2.00	
Keeping wedges tight	2.00	
		4.00
American:		
July—English:		
Keeping joints in shape	$ 2.00	
Keeping wedges tight	10.00	
Surfacing	5.00	
		17.00
American:		
Keeping joints in shape	$ 2.00	
		2.00
August—English:		
Keeping wedges tight	$ 8.00	
Keeping joints in shape	3.00	
Surfacing	10.00	
175 New wedges		
		21.00
American:		
Surfacing	$ 6.00	
Keeping joints in shape	2.00	
		8.00
September—English:		
Keeping wedges tight	$ 8.00	
125 New wedges		
		8.00
American:		
Surfacing	$ 6.00	
Keeping joints in shape	2.00	
		8.00
October—English:		
Keeping wedges tight	$ 6.00	
Keeping bolts tight	2.00	
Surfacing	20.00	
Lining	4.00	
		32.00

American:		
Surfacing	$ 10.00	
Lining	2.00	
		12.00
November—English:		
Surfacing	$ 12.00	
Lining	6.00	
Keeping wedges tight	5.00	
		23.00
American:		
Surfacing	$ 8.00	
Lining	4.00	
Keeping joints in shape	1.00	
		13.00
December—English:		
Surfacing	$ 15.00	
Wedges	5.00	
Joints	3.00	
		23.00
American:		
Surfacing	$ 6.00	
Keeping joints in shape	1.00	
		7.00
Total 1893:		
English		$143.85
American		72.40
1894—January—English:		
Surfacing	$ 22.00	
Gaging	15.00	
Keeping wedges tight	2.00	
		$ 39.00
American:		
Surfacing	$ 15.00	
Keeping joints in shape	1.00	
		16.00
February—No charge.		
March—English:		
Surfacing	$ 10.00	
Keeping wedges tight	3.00	
Keeping bolts tight	1.00	
		14.00
American:		
Surfacing	$ 6.00	
Keeping joints in shape	1.00	
		7.00
April—English:		
Surfacing	$ 6.00	
Keeping wedges tight	2.00	
		8.00

American:		
Renewing cross-ties	$ 59.00	
		59.00
May—English:		
Surfacing	$ 30.00	
Lining	6.00	
Keeping wedges tight	3.00	
		39.00
American:		
Surfacing	$ 15.00	
Lining	5.00	
		20.00
June—English:		
Putting in 123 cross-ties	$ 40.00	
Surfacing	40.00	
Lining	8.00	
Keeping wedges tight	6.00	
		94.00
American:		
Surfacing	$ 20.00	
Lining	5.00	
		25.00
July—English:		
Putting in 50 new wedges and keeping wedges tight	$ 3.00	
Tightening bolts	1.00	
		4.00
American:		
Tightening bolts	$ 1.00	
		1.00
August—English:		
Putting in 150 new wedges and keeping wedges tight	$ 4.00	
Surfacing	3.00	
		7.00
American:		
Surfacing	$ 3.00	
		3.00
September—English:		
Keeping wedges tight	$ 4.00	
Tightening bolts	1.00	
Surfacing	8.00	
		13.00
American:		
Tightening bolts	$ 1.00	
Surfacing	6.00	
		7.00

October—English:		
Surfacing	$ 6.00	
Lining	2.00	
Keeping wedges tight	3.00	
		11.00
American:		
Surfacing	$ 4.00	
Lining	1.00	
Tightening bolts	2.00	
		7.00
November—English:		
Surfacing	$ 7.00	
Keeping wedges tight	1.00	
		8.00
American:		
Surfacing	$ 3.00	
		3.00
December—English:		
Surfacing	$ 4.00	
Keeping wedges tight	2.00	
		6.00
American:		
Surfacing	$ 4.00	
Tightening bolts	1.00	
		5.00
Total 1894:		
English		$243.00
American		153.00
1895—January—English:		
Tightening bolts	$ 1.00	
		$ 1.00
American:		
Tightening bolts	$ 1.00	
		1.00
February—English:		
Tightening bolts	1.00	
Tightening wedges	1.00	
		2.00
American:		
Tightening bolts	$ 1.00	
		1.00
March—English:		
Tightening bolts	$ 1.00	
Tightening wedges	2.00	
		3.00
American:		
Tightening bolts	$ 1.00	
		1.00

April—English:		
Surfacing	$ 8.00	
Tightening bolts	1.00	
Tightening wedges	2.00	
		11.00
American:		
Surfacing	$ 5.00	
Tightening bolts	1.00	
		6.00
May—English:		
Surfacing	$ 2.00	
Tightening bolts	1.00	
Tightening wedges	1.00	
		4.00
American:		
Surfacing	$ 2.00	
Tightening bolts	1.00	
		3.00
June—English:		
Surfacing	$ 6.00	
Lining	2.00	
Keeping wedges tight	3.00	
		11.00
American:		
Surfacing	$ 4.00	
Tightening bolts	1.00	
		5.00
July—English:		
Keeping wedges tight	$ 4.00	
Tightening bolts	1.00	
		5.00
American:		
Tightening bolts	1.00	
		1.00
August—English:		
Surfacing	$ 8.00	
Keeping wedges tight	6.00	
		14.00
American:		
Surfacing	$ 3.00	
		3.00
September—English:		
Surfacing	$ 10.00	
Keeping wedges tight	6.00	
		16.00
American:		
Surfacing	$ 6.00	
		6.00

October—English:		
Surfacing	$ 48.00	
Lining	4.00	
Keeping wedges tight	6.00	
		58.00
American:		
Surfacing	$ 20.00	
Lining	3.00	
Tightening bolts	1.00	
		24.00
Total 1895:		
English		$125.00
American		51.00

SUMMARY.

Year.	English.	American.
1887 (3 mos.)	$ 70.77	$ 18.70
1888	458.94	178.56
1889	125.59	119.54
1890	158.31	85.07
1891	103.14	79.97
1892	179.18	69.63
1893	143.85	72.40
1894	243.00	153.00
1895 (9 mos.)	125.00	51.00
Totals, 8 years	$1,607.78	$827.87

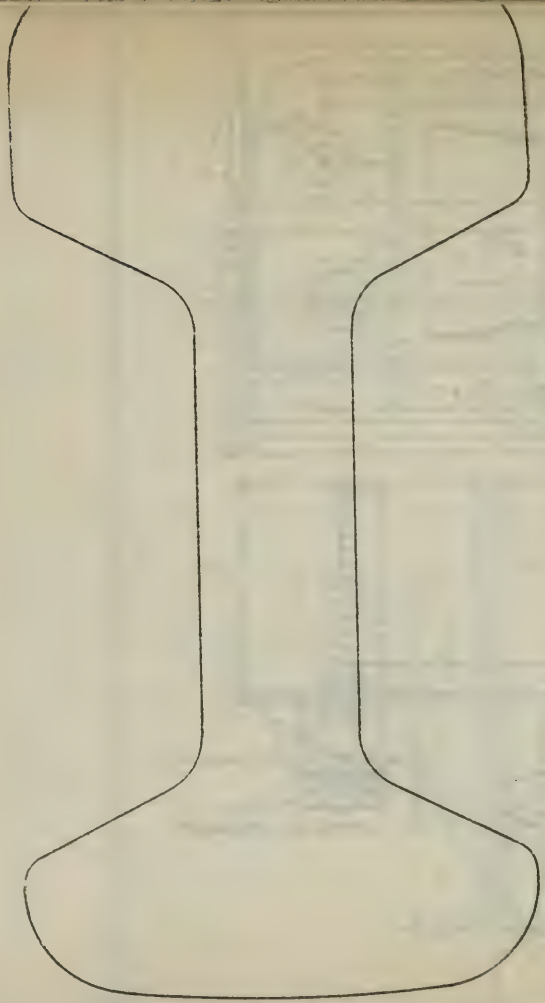
Being $200.96 per year per ½ mile, or about $402 per mile per year for the English, and $103.48 per year per ½ mile, or about $206.96 per mile per year for the American rail.

The experience with the English type of track on the Pennsylvania Railroad was unsatisfactory and so much so as to be almost annoying.

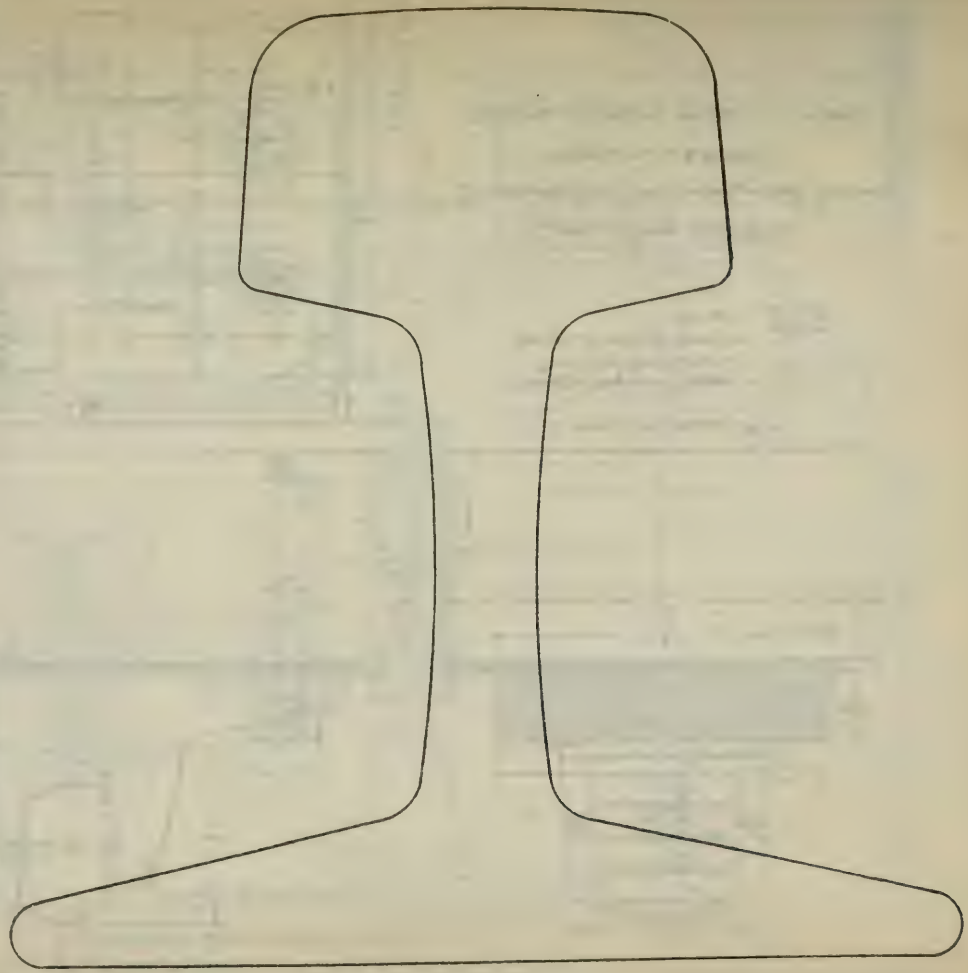
The difficulties encountered were the same on all divisions—the trouble in keeping track to true line and surface; creeping of the rails; loosening of the wedges; wide gage on account of wearing of rails, particularly on curves; and the constant care and expense incident thereto. The rails, however, were shown to be of good material.

The comparative cost of the maintenance for the English and P. R. R. standard tracks of the same length for the time the English rail was in track on the several divisions is shown by the following statement:

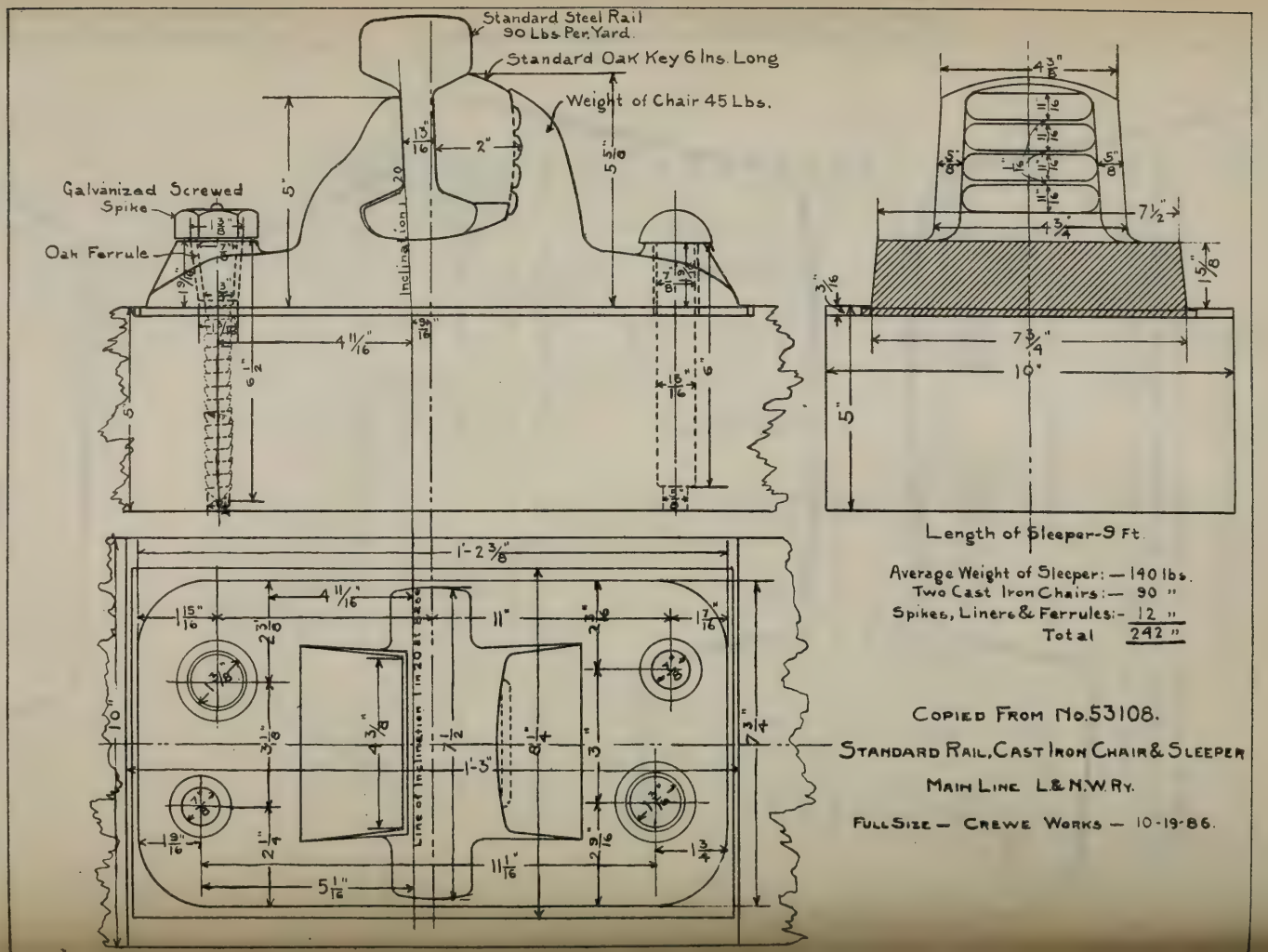
	NEW YORK		PHILADELPHIA		MIDDLE		PITTSBURG	
YEARS	P. R. R. Standard	English Standard 2430 ft. on Steel Cross Ties	P. R. R. Standard	English Standard 2460 ft. on Wooden Cross Ties	P. R. R. Standard 2520 ft. on Wooden Cross Ties	English Standard 2520 ft. on Steel Cross Ties	P. R. R. Standard	English Standard 2490 ft. on Wooden Cross Ties
1887. ...	No Detailed Record	.....	No Detailed Record Destroyed by Fire	No Detailed Record Destroyed by Fire	.....	677.44	18.70	70.77
1888.. ...		124.56			300.52	414.48	178.56	458.94
1889.. ...		365.24			122.60	152.05	119.54	125.59
1890.....		452.12			153.80	299.50	85.07	158.31
1891.....		375.84			132.00	548.80	79.97	103.14
1892.....		424.67			.....	.....	69.63	179.12
1893.....		533.84			.....	.....	72.40	143.85
1894.....		373.71			.....	.....	153.00	243.00
1895.....		356.07			.....	.....	51.00	125.00
1896.....		.....			.....	.....	.....	.....
Totals....	$2483.36	$3006.05	$1292.50	$1318.34	$ 708.92	$2092.27	$ 827.87	$1607.78
Cost of maintenance of the ½ mile of track per year..	$ 310.42	$ 375.75	$ 272.11	$ 277.55	$ 177.23	$ 523.07	$ 103.48	$ 200.97
Cost of maintenance per mile per year.....	$ 621.85	$ 751.50	$ 544.22	$ 555.50	$ 354.46	$1046.14	$ 206.96	$ 401.94



London & North Western Ry.,
Bull-Head Pattern, 90 lbs. per yard.



Pennsylvania Railroad,
"T" Rail Pattern, 85 lbs. per yard.



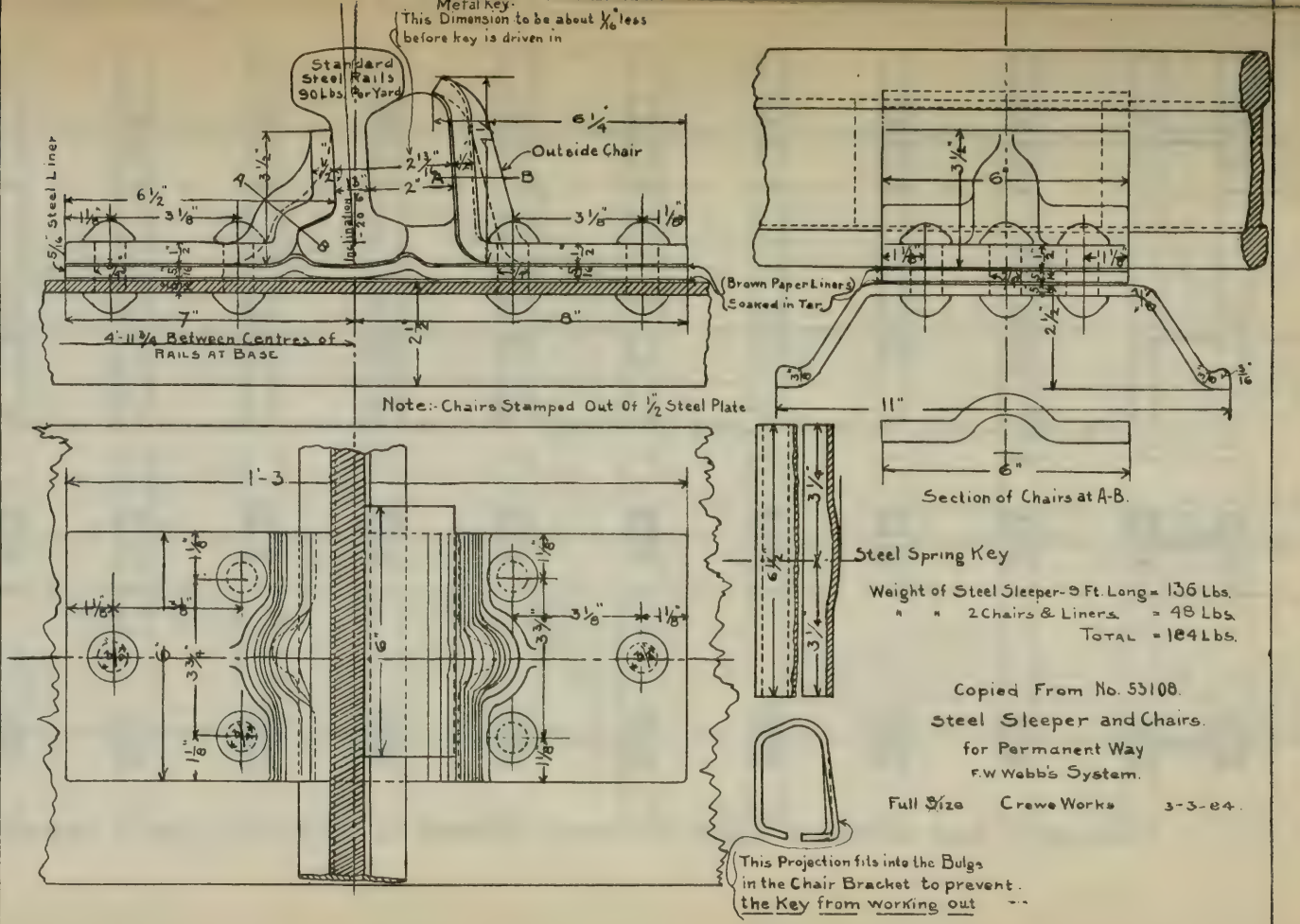
Average Weight of Sleeper:— 140 lbs.
Two Cast Iron Chairs:— 90 "
Spikes, Liners & Ferrules:- 12 "
Total 242 "

COPIED FROM No.53108.

STANDARD RAIL, CAST IRON CHAIR & SLEEPER

MAIN LINE L. & N.W. RY.

FULL SIZE — CREWE WORKS — 10-19-86.



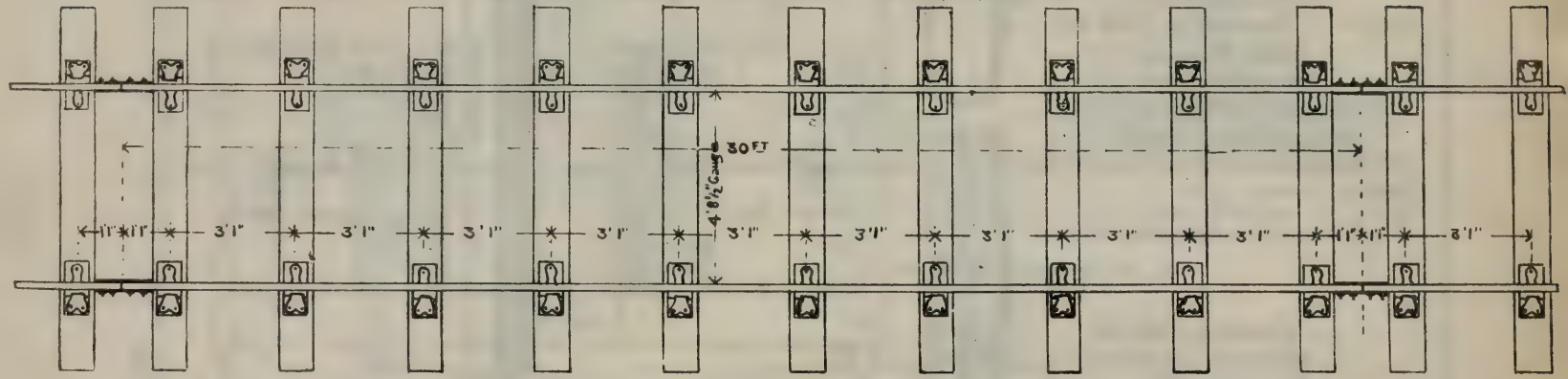
Weight of Steel Sleeper- 9 Ft. Long = 136 Lbs.
" " 2 Chairs & Liners = 48 Lbs.
TOTAL = 184 Lbs.

Copied From No. 55108.

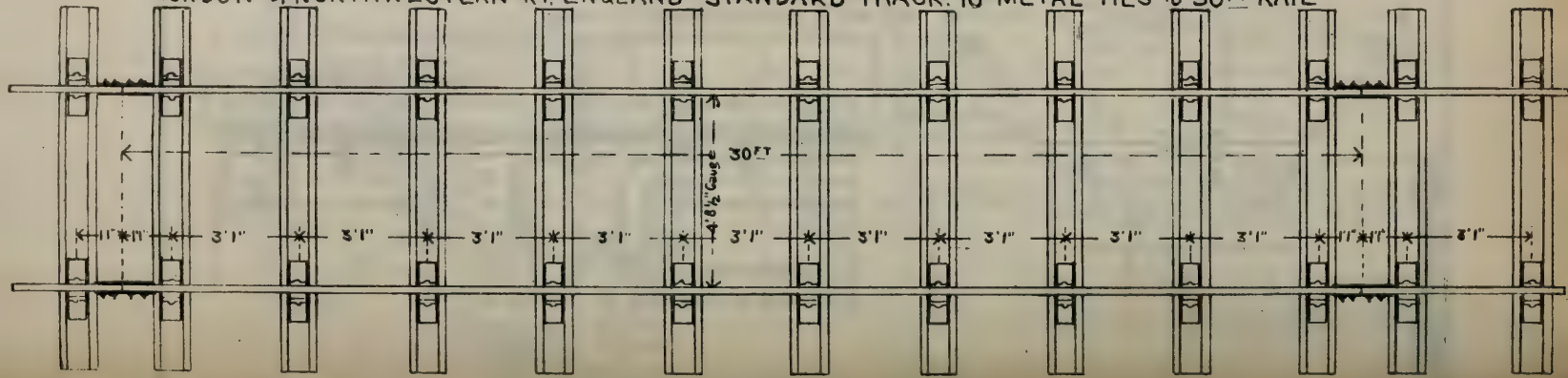
Steel Sleeper and Chairs.
for Permanent Way
F.W Webb's System.

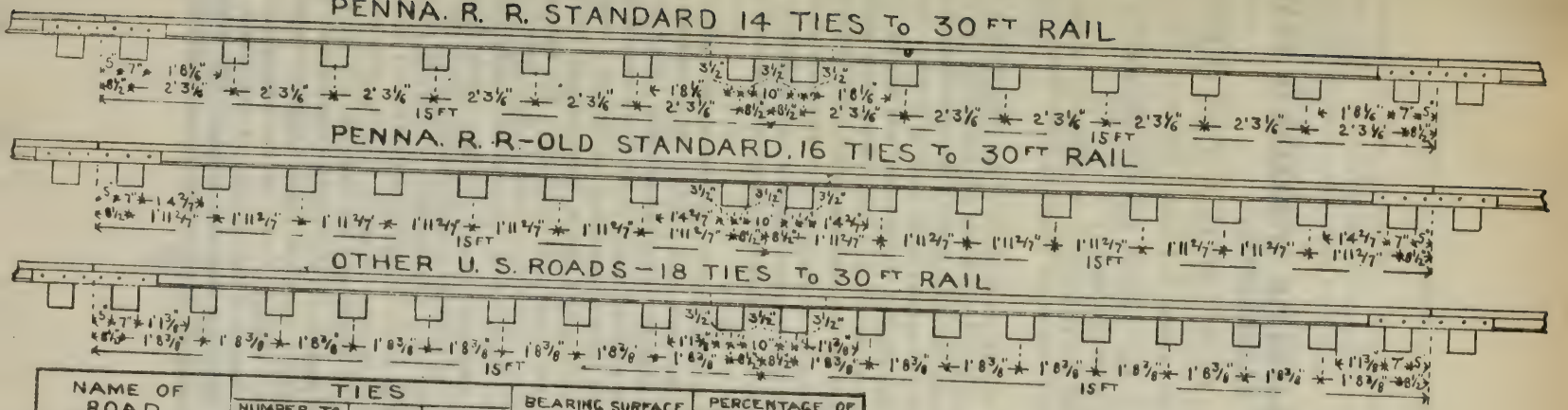
Full Size Crewe Works 3-3-84.

LONDON & NORTHWESTERN RY. ENGLAND—STANDARD TRACK, 10 WOODEN TIES To 30FT RAIL



LONDON & NORTHWESTERN RY. ENGLAND—STANDARD TRACK, 10 METAL TIES To 30FT RAIL




PENNA. R. R. STANDARD 14 TIES To 30 FT RAIL
15 FT
15 FT
PENNA. R. R-OLD STANDARD. 16 TIES To 30 FT RAIL
15 FT
15 FT
OTHER U. S. ROADS—18 TIES To 30 FT RAIL
15 FT
15 FT

NAME OF ROAD	TIES			BEARING SURFACE PER. 30 FT	PERCENTAGE OF STRENGTH ABOVE P.R.R STANDARD of 1897
	NUMBER TO 30 FT RAIL	WIDTH	LENGTH		
P.R.R. STANDARD	14	7"	8' 6"	69.42 Sq Ft	0.0
P.R.R. OLD STANDARD	16	7"	8' 6"	79.34	14.3
OTHER U.S ROADS	18	7"	8' 6"	89.25	28.6
L & N.W. R R	10	10"	9' 0"	74.97	7.7

SKETCH SHOWING
BEARING SURFACE OF CROSS TIES
ON PENNA. R.R AND LONDON & NORTHWESTERN R.R.
SCALE 1/4" = 1' SEPT. 20-1897.

DISCUSSION OF PAPER ON "STRESSES IN TRACK FASTENINGS."

(Published in Bulletin No. 104, Pro. 1909, Vol. 10, Part 2, pp. 1431-1455.)

By Albert J. Himes.

In his introduction to Mr. Stetson's paper on "Stresses in Track Fastenings," Mr. Cushing states on page 1:

"It is well-known that the problem of calculating the stresses produced in track fastenings is practically indeterminate;" and on page 22 Mr. Stetson says:

"In considering the results obtained from the computations in this study, the fact must not be lost sight of that the same degree of accuracy cannot be expected here as is obtained in most other calculations of stresses. There are many assumptions which have to be made, and many other things, such as irregularities in alinement and surface of track, sudden application and removal of load, etc., which may modify and change the results obtained by any computation from the actual results."

These statements should be emphasized, and it may be well for the sake of clearness, and to guard against possible misconceptions, to consider for a moment what is the proper function of mathematics in the practice of engineering.

The engineer is not a mathematician and he seldom needs to attain mathematical precision. He deals with material things and his work is always permeated by the imperfections which naturally belong to material things. He undertakes a problem in construction and finds through experience and education that his mathematical learning is a valuable aid. It assists his judgment and enables him to form a proper conception of the relative magnitude and importance of things. He has no precise knowledge of his problem, or any part thereof, save form. Geometry can be applied with a precision that is approximately mathematical. But the loads, material of construction and mechanical design do not admit a precision that can in any sense be termed mathematical. His load will vary between wide limits. It is seldom desirable to design for the maximum possible load, but it is not enough to design for the ordinary load. He must assume a standard safely in excess of ordinary service, but not as large as the extreme possibility. His material will be known experimentally to have a strength varying between wide limits. He cannot use its least strength because there are always abnormal results that are not at all representative. Neither can he use the greatest strength. He must assume for its strength a fair average of the results shown by experiment, rather a little less than the average. His design will be developed as far as possible according to well-known mechanical laws, but

the conditions for the fulfillment of these laws can be only approximately attained. In so far as they are not attained, it is necessary that he should provide for the most unfavorable conditions. With these things in mind, he produces a structure, a machine or engineering plant, and in so doing he may reasonably hope for success, even though his design be without precedent.

His work, then, is surrounded on all sides with uncertainty, uncertainty of load or duty, of material, and of theoretical correspondence of design with mechanical laws. Out of these uncertainties he develops a useful engineering work, and having passed the experimental stage, we are prone to examine it critically with reference to economy of construction. We seek to make its several parts conform more closely to some precise calculation, and in so doing lull ourselves into a dangerous feeling of security.

The mathematical determination of the exact strains which a structure does withstand presents so many difficulties that the effort is seldom worth undertaking and the sooner we recognize this fact the better it will be for the reputation of our profession. Engineering is regarded by the public as a precise art and too many of us appear willing to accept that description. The result is that every time it becomes necessary to explain away that fallacy, be it in a court of law, a legislative investigation or the forum of public opinion, we suffer a loss of prestige.

If we have not calculated that which it is believed we could and should have calculated, if we have applied a well-known formula beyond its limits with disaster, if at any time our calculations betray a lack of precision, then indeed do we present a sorry spectacle in the public gaze. And no one more than the engineer is responsible for this state of affairs. We do use mathematics, mathematics are absolute in their precision, and hence the deduction, which we generally encourage, that ours is a precise art. It is time to correct this state of things, and the correction can best be made by first disabusing ourselves of the idea that everything can be determined by figures, and then explaining as the opportunity affords, to men of other professions and to educated laymen, something of the true nature of our art.

With these things in mind it is desired to discuss somewhat critically the paper of Mr. Stetson and to make a plea for the experimental investigation of unknown strains in preference to that by means of mathematics.

Mr. Stetson's paper is an attempt to determine analytically the strains in track fastenings. His introductory statement of the forces acting might with greater clearness be rendered as follows:

(1) Gravity;
(2) Centrifugal force;
(3) Lateral thrust due to rigidity of wheel base;
(4) Longitudinal thrust due to movement of locomotive.

The resistances are:

(1) The supporting power of the track and roadbed;
(2) Friction of rail on wheels;
(3) Friction of rail on ties;
(4) Friction of ties on ballast;
(5) Shearing strength of spikes;
(6) Bearing strength of ties in contact with spikes;
(7) The stiffness of the rail.

He next computes the flange pressure, the first step of which is to determine the wheel loads. In arriving at the maximum wheel load, the centrifugal force has been assumed to act horizontally. This is incorrect. Its direction is parallel to the plane of the tops of the rails and this difference has an important effect in determining where the resultant pressure intersects the plane of the rail base. With this exception the computation appears to be correct. But since the result sought is the maximum flange pressure, which is a function of the wheel load, some mention should be made of the fact that imperfect counterbalancing, elliptical wheels and a super-elevation too small to counteract the centrifugal force will all tend towards a greater flange pressure and one that could easily be double that arrived at by Mr. Stetson for normal conditions. Since lack of counterbalancing and elliptical wheels are often the cause of broken rails, it may have been considered that these are maximum conditions; too great to be provided for. But inasmuch as these adverse conditions exist in all degrees from nothing to the point where rails are broken, it would be somewhat disquieting to think that the rail fastenings would be insufficient to resist their effects.

The aim of the calculations appears to be a basis for the design of track fastenings. The computations are elaborate and thorough. The analysis is very skilful. But we must judge the work by the results attained and with this criterion it does not appear to be worth the effort.

Mr. Cushing's table on page 24 is here rearranged so that the flange pressures increase consecutively:

Maximum Pressure in pounds	Speed in Miles per hour.
8,500	75.5
9,500	80.3
9,500	85.3
10,000	83.9
10,100	79.5
10.300	83.9
10,300	85.03
10,500	89.4
11,200	80.7
11,200	81.29
11,200	90.5
11,500	92.3
13,000	87.7

The lowest pressure, 8,500 lbs., is given for a speed of 75.5 miles per hour. The highest pressure, 13,000 lbs., is given for a speed of 87.7 miles, an increase of 4,500 lbs. pressure for an increase of 12.2 miles per hour of speed. The table also shows a pressure of 11,200 lbs. for a speed of both 80.7 miles and 90.5 miles, an increase of 9.8 miles per hour in speed with no change of pressure. The table here given is for a single class of locomotive. The pressures are measured, not calculated, and they were all recorded at the same place on a one-deg. curve. It is quite evident that any curve showing the variations of pressure as a function of the speed would be so irregular as to be worthless for purposes of calculation and design. And this is as it should be. The machine is imperfect and the roadbed is imperfect, and no close conformity to a law could be expected. It is not in the nature of things, nor do we care. We are concerned only with maximum pressures and the law of variation below that maximum is only of academic interest.

Mr. Cushing thinks the calculated pressures approximate the results of measurement sufficiently to indicate a possible success for the mathematical analysis, and shows a table of calculated pressures to support this view. The closest possible agreement to the measured results, which is shown therein, is a pressure of 11,500 lbs., at a speed of 60 miles per hour with super-elevation for 60 miles per hour, compared with a measured pressure of 8,500 lbs. at a speed of 75.5 miles per hour with a super-elevation for 70 miles per hour. Inasmuch as the latter speed exceeds that for which the track was elevated, the pressure, 8,500 lbs., would have been still less if the elevation had been adjusted for the speed, as it was assumed to be in the calculations. The comparison should therefore be made between something less than 8,500 lbs. at 75.5 miles per hour and 11,500 lbs. at 60 miles per hour. When we remember that in the calculations the centrifugal force was applied horizontally instead of parallel to the plane of the rails, it is seen that 11,500 lbs. is theoretically too small, so that we have finally an increase of speed of 15.5 miles per hour accompanied by a decrease of pressure of much more than 3,000 lbs., a very absurd result.

At 87.7 miles per hour and a super-elevation for 70 miles per hour, the measured pressure was 13,000 lbs., while at 70 miles per hour with a super-elevation for 60 miles per hour the calculated pressure was 12,950 lbs. This is an agreement of pressures, but the speeds are 17.7 miles apart, and if as in theory the unbalanced centrifugal force varies with the square of the speed the agreement fails.

Among the many imperfections which interfere with calculated results, it may be stated on the authority of a prominent member of the M. C. B. Association that 45 per cent. of the cast-iron car wheels in service run to the flange because of mismating with respect to diameters. There is little reason to expect greater perfection in the worn tires of driving wheels. Again, a report of the behavior of a certain class of locomotives said, "they ride hard and thrash around a great deal." These

things must influence the flange pressure, but their effects cannot be computed.

In "The Results of a Series of Investigations," by Geo. L. Fowler, M. E., published by the Schoen Steel Wheel Company, there is given on pp. 118-121, inclusive, a tabulation of flange pressures for a 100,000-lb. capacity car on a 4-deg. 25-min. curve, measured on the P. C. C. & St. L. Railway. The outer rail was elevated for a speed of 36.6 miles per hour. This table shows for a speed of 19.03 miles per hour pressures of 16,785 lbs. and 5,090 lbs. For a speed of 31¼ miles per hour it shows a pressure of 11,025 lbs. and 7,775 lbs. Is anything more needed to demonstrate that the actual pressures are due to imperfections, rather than to the strict operation of mechanical laws? In table 1 of Mr. Stetson's paper there is given for Class C locomotives on a 5-deg. curve a pressure of 13,100 lbs. for a speed of 40 miles per hour and super-elevation to match. If the calculations give for the heaviest locomotive at 40 miles per hour, with proper super-elevation, a pressure that is less than the pressure due to a 100,000-lb. capacity car, at 19.03 miles per hour, and a super-elevation for 36.6 miles per hour, is it safe to design according to the calculated pressures?

On page 117 of the above-mentioned book, Mr. Fowler also reports a car pressure of 16,175 lbs. with a speed of 14.35 miles. On page 125 Mr. Fowler has deduced flange pressures for a 100,000-lb. capacity car on a 4-deg. 25-min. curve as follows:

11,408 lbs. at 36.66 miles per hour;
12,978 lbs. at 40 miles per hour;
15,415 lbs. at 45 miles per hour;

and these he considers minimum values.

Much more might be said to show the futility of any attempt to determine actual stresses in existing structures by means of mathematics, but it may be more profitable to discuss the true way to determine such stresses, that is, by actual measurement. It should be said, however, in passing, that on no account is the use of mathematics for purposes of investigation to be condemned. A careful analysis of a difficult subject, by means of mathematics, will result in a clearer conception of the relations involved, and thus permit a more intelligent treatment of the subject. For instance, Mr. Stetson's conclusions on pp. 20 and 21, in which he compares the relative effects of different locomotives, different curves, speed and super-elevation, are an excellent example of the legitimate deductions from an investigation of this sort. It is only when he puts his results in figures and attempts to decide the actual number of spikes to use that danger appears. If lack of consideration or overconfidence should cause one to rely on these computations, his results might well be disastrous.

Mathematics are applied with great success in bridge design, although, even there, the hypotheses upon which the calculations are based are only approximately fulfilled. A pile-driving formula seems a fitting use for a mathematical expression of experimental data. In building an important

bridge, which had to be founded on piles, a careful record of each pile was made, its safe capacity figured by Wellington's formula, and then each pile was given only one-half of its calculated safe load. The bridge has never settled. Perhaps too many piles were driven, but other bridges have settled, and this one being of unusual design, where any slight settlement would have occasioned great annoyance, it was considered worth while to be a little prodigal with the foundation. The foundation could not well be strengthened later should a settlement occur.

The case of railroad tracks is very different. With thousands of miles of track in constant service and hundreds of thousands of trains, it is no difficult matter to study the behavior of the track and to strengthen it at the first sign of weakness. This is what is being done every day and all the time. We do not need to compute what we already know. It is so seldom that tracks spread or rails turn over, considering the vast amount of traffic, that such things need give but little concern. If it suddenly becomes necessary to use a new locomotive of very extraordinary design, then of course it will be impossible to say from experience whether the track fastenings will be safe and such a case might be the subject of computation. But in the absence of definite knowledge, a very safe and proper precaution would be to keep the speed well within bounds until sufficient experience had been acquired to judge correctly of its safety.

When experience is not available and where computation is impracticable, it is still possible in almost every instance to arrange in some manner to produce the anticipated conditions and observe their effects. The mechanical engineers have long pursued this course and with great success. Witness the pony brake, the duty trials for pumping engines, the arrangement for testing locomotive counterbalancing, and a host of other appliances and devices to determine by actual measurement the results that at best are only indicated by computation.

No finished machine or structure can be evolved by study alone. It must be supplemented by experience. All things develop. Any design should be based upon precedent and experience, upon theory and upon experiment. These are our sources of information and upon the correct interpretation and correct application thereof depends success.

COMMENTS BY E. E. STETSON.

Referring to the attached discussion of Bulletin 104 by Mr. Himes, the principal comments I have to make are on the part of the discussion on pp. 5, 6 and 7, where Mr. Himes compares the calculated wheel pressures with the measured wheel pressures. They are as follows:

(1) In comparing the calculated pressures with the measured pressures as obtained in the Pennsylvania Railroad tests with a Class "B" locomotive on a 1-deg. curve, Mr. Himes states that the closest possible agreement to the measured results which is shown therein is a pressure of 11,500 lbs. at a speed of 60 miles per hour with super-elevation for 60 miles per hour, compared with a measured pressure of 8,500 lbs. at a speed of 75.5 miles per hour, and from this comparison shows that we have

an increase of speed of 15.5 miles per hour accompanied by a decrease of pressure of much more than 3,000 lbs., which he states is a very absurd result. In the following paragraph Mr. Himes shows that in cases where the computed and measured wheel pressures were the same, the speeds were 17.7 miles apart and therefore the agreement fails. I think that the agreement between the calculated and measured pressures is much closer than indicated by Mr. Himes for the reason that it is the *unbalanced* speed and not the absolute speed that affects the wheel pressure. The wheel pressure at a speed of 40 miles per hour with a centrifugal force balanced would be practically the same as the wheel pressure at a speed of 70 miles per hour with centrifugal force balanced, other conditions being the same. In comparing the calculated with the measured results, therefore, it is the unbalanced speed that should be considered. The closest agreement between measured results of Pennsylvania Railroad tests and calculated results is the measured result of 11,200 lbs. for a speed of 80.7 miles with super-elevation for 70 miles per hour and a calculated result of 12,950 lbs. for a speed of 70 miles per hour with super-elevation of 60 miles per hour, or an increase in pressure of 1,750 lbs., accompanied by a decrease in unbalanced pressure of 0.7 miles, which is not an absurd result when it is remembered that the weight of the locomotive used in the test was less and spacing of wheel different from the locomotive used in the computations. Also for the case cited by Mr. Himes where the pressures agree it should be noted that the unbalanced speeds are only 7.7 miles per hour apart.

(2) On pp. 6 and 7, Mr. Himes compares the results of series of tests made by Mr. George L. Fowler at Burgettstown, with a 100,000-lb. capacity car on a 4-deg. 25-min. curve, with the calculated pressure given in Bulletin 104, and shows the pressures obtained with the 100,000-lb. capacity car exceeded the calculated pressures for the heaviest locomotive. I was present when Mr. Fowler made these tests and do not think the results obtained are very reliable. His measuring device was too sensitive in my opinion to give accurate results. Then, too, the gage side of head of the short section of rail, against which the pressures were recorded, was not always flush with the head of the adjacent rail at the joint, but left a slight projection for the wheel to strike against. When the car wheel first struck this section of the rail the needle which recorded the pressure would sometimes jump entirely off the paper from the quick shock or impact received. For this reason I feel that Mr. Fowler's results are too large, and not as reliable as the Pennsylvania Railroad tests.

(3) On page 8 Mr. Himes states that "it is so seldom that tracks spread or rails turn over, considering the vast amount of traffic, that such things need give but little concern." I would take exception to this statement, for it seems to me that next to broken rails, spreading rails have been the source of the greatest number of recent railroad wrecks.

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